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LANDING ON AIRLESS PLANETS

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Although perfection of techniques for landing on bodies with atmospheres must logically precede any attempt to land on an airless body such as the Moon, the latter problem is worth some preliminary consideration at this stage, as the requirements for a suitable vehicle to make such a landing are difficult to embody in a machine capable of performing both functions efficiently. This lends weight to the claim that considerable advantage could be gained if it proves possible to use different vehicles for each operation.

If we assume that the emergence into interplanetary space follows the same general pattern of development as most other scientific advances, we should expect to see steady progress by a series of small steps, each step arising out of the successful conclusion of its predecessor. We can, therefore, visualise the progress of atmospheric flight to yet greater heights and velocities, until a winged rocket-propelled vehicle is produced which accelerates rapidly upwards through the atmosphere, turns over into horizontal flight and coasts through frictionless space under built-up momentum. This line of development leads on directly to the "orbital rocket."[1]

If we now assume that it will be possible to telecontrol unmanned rockets carrying a serviceable payload of fuel into an orbit with sufficient precision these could provide a reserve which could be transferred in the orbit to another rocket. This will enable the receiving machine to extend its range of operation by transforming its circular orbit into an elliptical path by means of an additional impulse and on returning to the same point, to revert to the circular orbit by applying a decelerating impulse of the same magnitude. The additional velocity required to carry the vehicle to the Moon's distance is small in comparison with the original orbital velocity[2] and seems well within the bounds of structural feasibility.

If we now consider a variant of the "orbital rocket" of the same overall design configuration, but having a top step replacing the "winged" component, this can be a specially designed "transit component" intended to effect a Lunar landing. It will be stripped down to the essential structure in order to save weight, be unmanned and telecontrolled. This vehicle will be designed to provide the features discussed later, and be so dimensioned that it can be contained inside a false fairing during its transit through the atmosphere.

The gross weight could be kept within the limits assigned to the winged ferry rocket, and therefore could be brought to orbital velocity by the same "Booster" stages.

When ferry rocket, tankers, and transit component are safely established in their orbital rendezvous, fuel stores and personnel would be transferred[3] and the circumlunar voyage commenced.

This procedure involves an overall expenditure of equipment and fuel far greater than would be required for a single vehicle, but an important dual advantage is claimed, viz. the gross weight of any one component is reduced by a very large factor and we are liberated from the restriction of making one design cover the conflicting requirements of the aerodynamic phase and the rest of the voyage.

As will be apparent later, wings and aerodynamic control surfaces must considerably increase the deadweight to be landed, and are a useless encumbrance, making the craft more difficult to handle in the approach. If we assume that the crew will transfer to a waiting "winged ferry" on their return to the orbit, these aerodynamic adjuncts may safely be omitted.

We may now consider the requirements we would like to find in the ideal vehicle for a lunar landing, but before doing so should review what is known of the Lunar surface in particular reference to this project.[3]

Observation has established a fair general picture of the lunar surface, and much can be deduced from knowledge of the conditions prevailing there. Extremes of temperature must have given rise to considerable splintering of the surface, and, owing to the low gravitation and lack of water, there has been little consolidation by packing or sedimentation. There will be a dust layer, but this has been exaggerated in some quarters and its thickness is a matter of some uncertainty. Recent conclusions tend to discredit the belief that a ceaseless rain of meteoric particles falls on the Moon. There is neither evidence to show that it does happen nor reason to suppose it should, and the theory that some of the flat crater floors are veritable dust bowls is no longer regarded seriously.

No matter what may have been the cause of the lunar craters, the areas immediately adjacent to any sharp gradients must have been, or are being, subjected to stresses, and are therefore liable to be unsound. On the other hand, the centre of large areas of similar terrain are more likely to be stable, and give the pilot an opportunity to misjudge laterally without prejudice to a safe landing. Many artist's impressions show the lunar rocket posed against a towering range of mountains, but that sort of landing would come under the general description of "wilfully hazarding the ship" if made intentionally.

A preliminary survey of the surface from an orbiting rocket, using infra-red photography at dawn and dusk should show up any idiosyncracies of thermal conductivity. The areas which were slow to cool would indicate solid rock, while those which cooled rapidly, or heated rapidly, would indicate dust. A few test drops on typical areas should serve to establish the kind of terrain safe to land on. A careful photographic study from close range would also help to establish the flat and solid areas. There will be no prepared runways

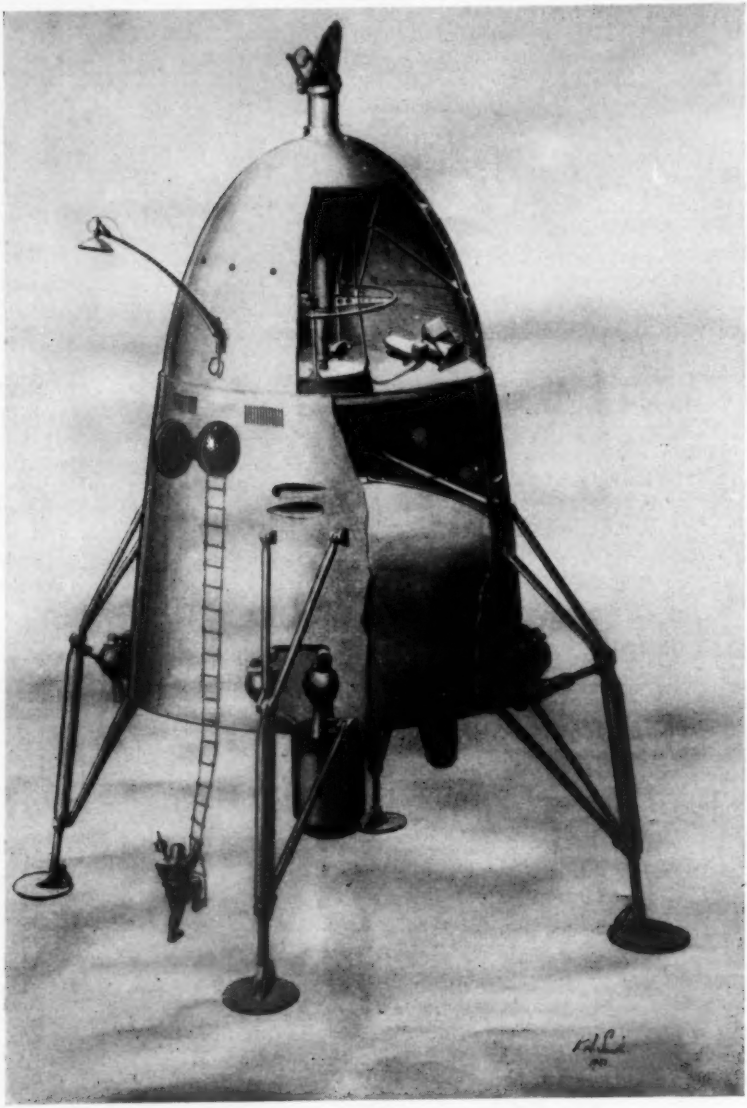
waiting on the Moon, so we shall have to accept whatever nature has provided. It must be remembered that the Air Force definition of a good landing as "One you can walk away from" will not be good enough on the Moon.

Owing to the fact that the Moon is airless, any question of gliding-in along a slanting path is not feasible. Orbital velocity close to the lunar surface (1·65 km./sec.), although small by some standards, is still much too great to be safely taken out by skidding across the surface, especially when the nature of that surface is considered a little more carefully. If a reasonable rate of deceleration is employed (say 0·05 km/sec.^{2}) the vehicle will fall under lunar gravitation as its velocity proceeds to decline below the orbital requirement. A simplified version of this calculation, using approximate values, gives the distance of fall as 0·431 kilometres, and the speed attained as 34·1 m./sec. vertical component, assuming the braking force to be exerted continuously parallel to the surface. This indicates that the final contact with the surface would be vertical in any case, whether the approach be from an orbit or otherwise.

We now have to consider a vehicle which will alight vertically, and must have its rocket jet facing downwards in the final moments of the descent, if the retarding force is to be utilized efficiently.[4] If the ship alights in this attitude it will have the additional advantage of being correctly positioned for the take-off. Lacking atmosphere, there are no damping or other stabilizing forces present, so if there is any asymmetry of thrust a couple will be produced tending to rotate the vehicle. Means must be provided to counter this, and the obvious step is to use the method employed to produce the changes of attitude required during the voyage for navigational requirements. This may take the form of flywheel reaction, swivelling motors, deflector plates in the efflux, or auxiliary jets. The most simple and direct means seems to be that of using auxiliary jets. The final choice must rest on questions of detail design, however, and an important factor will be the relative controllability of the thrust of the auxiliary motors. There must be at least three of these, unless one is prepared to rotate the ship to bring the line of thrust of the steering motor, and the centre of gravity of the ship, into a common plane with the desired plane of turning. The thrust requirement of the auxiliaries need not be very great if their line of action gives sufficient moment arm around the centre of gravity. Controllability within narrow limits is the most stringent design requirement. The moment produced by their maximum thrust should be sufficient to produce a rate of rotary acceleration of the order of 60 degrees/sec.^{2} when operating to overcome the moment of inertia of the vehicle at the condition of loading which applies at this phase.

Obviously, the greater the moment arm these auxiliaries command, the greater the degree of precision obtained for the same percentage of thrust control. Also the greater the moment arm, the less actual thrust they will need to exercise the same controlling effect.

It is very important that the vehicle should also be stable after landing, as it is impractical to make the structure sufficiently robust to withstand toppling over. This would be disastrous in any case, owing to the fact that no cranes would be available to right it. One therefore visualizes a system of



Lunar Spaceship

landing legs with a built-in shock-absorber system. At maximum deflection they must ensure that the venturi is clear of the ground and have a stroke such that the deceleration stresses to which the passengers and inert masses are subjected do not exceed a safe limit. A designed maximum of 0·10 km./sec.^{2} when arresting a drop from a height of 120 metres will require a stroke of 2 metres. Springs cannot be used of course, as they simply store energy, and do not dissipate it except by hysteresis. It is assumed an oleo system will be used, in which hydraulic fluid is driven by a piston through a constriction, thus dissipating its pressure energy in viscous drag. The oleo cylinders must be capable of withstanding the pressure needed to be applied over the total piston area to produce the retarding force, and it may be necessary to provide a means of heating the hydraulic fluid to ensure that the system does not freeze up.

Owing to the uncertain nature of the lunar surface, it would be unwise to use only the minimum number of legs to ensure stability, as one of them might easily find a weak area and prove incapable of taking load. For the same reason some device should be used to distribute the leg reaction over as wide an area as possible.

Let us consider an instance where a 24 ton ship has four legs. Each must sustain the maximum reaction at 10 g. which calls for 60 tons from each, so if we allow a bearing load of 25 kgm./cm.^{2} each foot must have a contact area of 400 cm.^{2}, giving a diameter of 22·6 cm. Load will remain on these areas during the whole period of stay in contact with the cold lunar surface, and rubber or similar material would lose its elasticity. In fact, wheels of any type would be pointless as the surface is unlikely to be suitable for any kind of rolling action. For this reason, it seems that the retraction motion should be straight up and down. Legs which splay out would be likely to dig in and their tendency to slip would be absolutely unpredictable.

In general, it would seem advisable to have the landing legs carried well outboard, so that the vehicle could be landed at a slight tilt, on a sloping surface or with a slight lateral velocity component. The classical problem of stability applies here and the line of reaction from the leg must pass above the centre of gravity through the range of permitted conditions, so that a couple is produced tending to oppose the tilting moment. It must be remembered, however, that a concentrated load in the centre of a big span will impose severe bending moments on the supports. This is a good reason for adopting a configuration which gives a vehicle of small height to diameter ratio, which is directly opposed to the aerodynamic optimum requirement.

A typical configuration is shown in the illustration and it will readily be seen that this is radically different from the "supersonic submarine" school of rocket design. Not only is it different from any rocket yet built, but it may also be different from the design solution actually adopted. I myself hope so, as it is pre-eminently unaesthetic.

Apart from the mechanical problems of the act of landing, there is also the problem of a suitable approach technique. There are the alternative methods of direct radial approach or of orbital approach. The direct method saves time, and under certain circumstances, fuel, but the orbital technique will probably be used because it is easier to handle. By setting oneself in some

unspecified orbit, it is possible, by noting the period and apparent variation of distance between apogee and perigee to predict, with great precision, future positions and velocity at any time. This may be done at leisure as no energy is lost in orbiting, and there is no likelihood of the position becoming critical. By a series of calculable impulses it will be possible to modify the original orbit to some desired form of circular orbit at a predesigned distance.

The great advantage of this method is that the orbital period is a very positive method of establishing distance. By adding impulses at right angles to the orbital plane, it will be possible to make the orbiting vehicle pass directly over some designated spot on the surface, and now, knowing the distance and velocity, it will be possible to calculate the impulse needed to bring the vehicle to rest at some target height and position. As this manoeuvre progresses it will be possible to check the accuracy of its performance and apply minor corrections.

Radar methods could give figures for distance and velocity with far greater precision than the pilot's capacity to manoeuvre could command. Within a few seconds of arrival at the target point the precise position would be known and the vessel could be allowed to fall freely until the final deceleration impulse commenced. This would start at about 600 metres and be complete by 40 metres from the surface. The error might be of the order of plus or minus 20 metres, which the shock absorbers could deal with. If desired, the steering motors could be used to reduce the rate of sinking to 7 m./sec., which in the case of a 20 ton vehicle would call for 114,000 kg./sec. impulse, using perhaps 570 kgm. of fuel at 200 S.I. (the steering motors might use low grade fuel of this order of specific impulse to ensure reliability and controllability).

Obviously this sinking manoeuvre would be very wasteful and the art of pilotage would lie in reducing this operation to the minimum, especially in view of the fact that this fuel has had to be ferried through a considerable gravitational gradient, and is therefore very valuable.

One of the immediate disadvantages of this cautious method of approach would be that one would land on a red hot surface, in the middle of a self-made dust storm. This might confuse the radar altimeter, and it is even possible that small rocks might bounce up off the surface, causing damage to the underside of the vehicle. A considerable degree of confidence would be called for, and that is usually the fruit of experience. For this reason it might be wise to practice landing a telecontrolled mock-up, as one learns only from the accidents one survives.

The conclusion to be drawn from this very general survey is that the practical method of approach may differ considerably from the "minimum energy" concept built up solely from considerations of celestial dynamics. There are a great number of practical problems yet to be solved, but the passage of time and the accumulation of experience as the subject progresses should yield valuable insight into the real difficulties. In view of all the minor points that have to be solved I think it is only fair to point out that some of the optimistic predictions about landing on Mars in 25 years and so on are irresponsible nonsense. It is one of the most trying features of constructive research that the major delays are almost inevitably caused by minor problems. I shall be

very happy if I live to hear that the first manned landing on the Moon has been successfully achieved, but I must confess to a strong conviction that it will take just too long for me to see it.

I would like to conclude by mentioning that the opinions expressed in this paper are my own, and to thank the Chief Scientist, Ministry of Supply, for permission to read this paper.

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PLANETARY ENGINEERING

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SUMMARY

The paper examines the possibility of changing the orbits, periods of rotation and inclination of the axes of planets. Sources of power on other planets, other than atomic power, are then considered, solar energy and wind-power being thought the most promising possibilities. The effects on Civil Engineering projects of values of g ranging from zero upwards are considered, together with the effects of extremes of temperature, and of atmospheric pressures and compositions encountered on other planets. The paper concludes by considering certain specific problems, such as the effect of these conditions on the setting action of concrete.

Many papers have been written on interplanetary travel, and the preliminaries thereto, but few have dealt with the theme of what happens after arrival. This paper is primarily concerned with this somewhat neglected field and although the civil engineering profession embraces all types of engineers who are not military—hence the name—no one man can know the whole gamut, and the author of a paper such as this is immediately on insecure ground when he ranges outside his own specialized field—in my own case, structural and municipal aspects of the subject.

In *Worlds in Collision*, Velikovsky conjured up visions of celestial holocausts in which the forces of nature played havoc with orbits, the length of the day, and other such items, and it may well be asked whether such effects could be obtained artificially and in a controlled manner by feats of engineering. However, the answer is disappointing. The close approach of a mass of planetary order may play havoc with orbits, but could not have much effect upon the rate of rotation of the planet approached. The only force which could slow down the rotation period is tidal friction, and its effect is negligible, except over a period of centuries. Most of us will, to say the least, feel sceptical of Velikovsky's theory that the Earth stopped rotating, then reversed its direction of rotation and started going round the other way, stopped once again and continued rotating in the original direction all in the space of a few hours!

Similar considerations apply to a conjectured tilt imparted to the Earth's

axis. One of the best-known fictional applications of the latter theme is Jules Verne's semi-satirical tale *The Purchase of the North Pole*. In this story, an effort was made to tilt the Earth by the tangential firing of suitably-placed explosives, the intention being to bring a more temperate climate to the polar regions, for the purpose of exploiting the mineral wealth there. Fortunately, when the charges were touched off, nothing happened, because too many zeros had been accidentally omitted from the calculations!

More recently, in *The Nature of the Universe*, Hoyle wrote ". . . No one has yet seen the other side of the Moon. But we might live to do so. If to-night a chunk of material the size of a mountain should strike the Moon obliquely, there is no doubt that the Moon would be set in rotation again, and the unseen side would turn slowly towards us." How right Hoyle was when he said "slowly"! If we interpret "a chunk of material, the size of a mountain" as a cubic mile of granite, and assumed it to strike the Moon tangentially at 50 miles per second, it would impart to the Moon an increased rate of rotation amounting to one extra revolution in about 12,000 years. Surely Hoyle was crediting someone with an extraordinarily long span of life!

It is of interest to add that, if the same chunk of material were to strike the Moon's surface perpendicularly, it would increase the Moon's linear velocity by about a yard per day. But this effect would not, of course, be cumulative; a month later, the Moon would be in exactly the same place as if there had been no impact, and the only effect of such an impact would be to change the dimensions of the Moon's orbit by a few yards!

The import of this is that forces capable of treating the rotation and orbits of celestial bodies like ninepins, simply do not exist. If we were in a position to impart a velocity of 50 miles per second to a cubic yard of granite, never mind a cubic mile, most of our astronautical problems would be solved.

Although there may be something to be said in favour of changing the orbit of a celestial body, to change the length of the day thereon is, surely, quite unnecessary, and not worth doing. Future astronauts will very quickly have to get used to days and nights independent of a 24-hour, or any other, clock. Already submarine crews and polar explorers are quite independent of the 24-hour day, without any serious adverse effects, and this is certainly one of the lesser difficulties in the way of space-travel!

One of the first jobs required of the engineer, even in a semi-permanent colony on another planet, will be the provision of a source of power. The uninitiated optimists may regard atomic power as the cure-all for all power problems, but it is not as easy as this. We may be in a position to set up a semi-permanent colony outside the Earth long before atomic power is fully reliable, and there may be circumstances preventing its use, e.g. dangerous radiation. As it is always desirable to have a stand-by in any case, other sources of power should be considered.

Solar power will almost certainly be used to a large extent where it is available:—that is to say, mainly on the inner planets and their satellites. It will not be of much use at distances further out than Mars, but it will really come into its own on airless bodies, where it can be relied upon without any interference from clouds, etc. On Earth it has been found that 183 square

feet of mirroring, suitably set up, can generate one horse-power; and there have been several experimental solar plants in various parts of the world, mainly desert areas, for some time. On the Moon and artificial satellites, whose distance from the Sun may be regarded as substantially the same as that of the Earth, considerably better figures will be obtainable, as there will be no atmosphere to absorb the Sun's energy. The corresponding figures at the distances for other planets can be easily calculated, being, of course, more favourable in the case of Venus and Mercury, and not so good in the case of Mars and its satellites. Solar energy would also be usable on some of the minor planets.

Some people, having learned that Titan has an atmosphere of methane (or marsh gas), and knowing methane to be combustible, might be tempted to suggest using this for power—but neither methane nor any other fuel is of use without oxygen. For this reason, such planets are perfectly safe from atmospheric explosions! Some substances will burn in gases other than oxygen; magnesium, for instance, will burn in nitrogen, and if free magnesium were found in sufficient quantity on a planet with a nitrogen atmosphere, the fuel problem might here be solved. It is unlikely that even imported fuels will be used to a great extent on the other planets unless there is a goodly proportion of oxygen in the atmosphere; the large-scale importation of oxygen for mere combustion is a very long way off yet!

While on this subject, it would be as well to add that the importation of an atmosphere to an airless planet is impracticable; even if it could be done, the atmosphere would not usually be retained. If a planet or satellite were capable of holding an atmosphere, it would probably possess one already.

Where there is water or other liquid on a planet, hydro-power might well be considered. This might be the case on Jupiter, in the unlikely event of that planet ever being colonized, liquid ammonia being used, probably in a device comparable to a water-turbine or Pelton wheel. Similar considerations apply to tidal power.

Wind-power might be used where there is an atmosphere. On Venus and the outer planets there is certainly unlimited wind-power available, the atmospheres being always in a state of turbulence, and it might probably be usable even on Mars. The actual form it could take might be in the nature of a wind dynamo—something which bears to the old-fashioned windmill the same relationship that the Pelton wheel or water-dynamo bears to the old flat-bladed water-wheel.

Another possibility is, of course, making use of any internal heat on the other planets.

Turning to more general matters, there are three very important factors which will influence engineering projects on other planets. These are:—(i) variations in the value of g, (ii) extremes of temperature, beyond those encountered on the Earth, and (iii) atmospheres with pressures ranging from zero almost to infinity, and of almost any composition.

Let us consider these three factors, in that order.

Values of g will range from zero, or nearly so—in the case of artificial satellites, some of the minor planets, and satellites such as Phobos and Deimos, (cases of some importance, as these may well be the next bodies to be visited after

our own Moon)—up to several million *g* in the case of some of the white dwarf stars. However, unless some revolutionary method is discovered of offsetting gravity, it is unlikely that permanent, or even semi-permanent, colonies will be set up where it exceeds 4 *g*. So far as the Solar System is concerned, this only eliminates the Sun itself, not a serious matter! On Jupiter, gravity equals $2\frac{1}{2}$–3 *g*, which may well be too much for colonization, but everywhere else it is much less, being nowhere more than about 1·1 *g*—substantially the same as on Earth.

The advantages of a low value of *g* are obvious; everything weighs less and is correspondingly easier to handle. But there are disadvantages, too: for instance, counterweights of cranes will be lighter, so the crane can lift no more than on Earth without overturning, unless the counterweight is increased. The same considerations apply to other structures which depend for stability upon weight; dams, retaining walls and arches, for instance, even though carrying a lighter load, will fail through instability if they are more heavily loaded than on Earth.

On the question of extremes of temperature, it is known that temperatures far higher and far lower than any experienced on Earth will be encountered, sometimes even side by side. On the day side of the Moon, for instance, the temperature will be higher than boiling point in the sunlight and perhaps a few hundred degrees lower only a few yards away in the shadow of a mountain. It will almost certainly happen that a structural member, such as a beam or stanchion, will have one end under the former conditions, and the other under the latter. The internal and secondary stresses due to the difference in temperature will be terrific, though not impossible to cope with if good conducting materials are used; but poor conductors of heat will have to be eliminated. For the same reason, expansion joints will inevitably be a most important feature of structures on other planets.

These extremes of temperature will render difficult the construction of buildings; thermal insulation will obviously be necessary, but this is irreconcilable with good conductivity, because the two qualities are diametrically opposed to each other. The form of construction will probably consist of a double skin, the outer one being a good conductor, to even out the internal temperature, and the inner one having good thermal insulation qualities. Where the two skins are inevitably bound up together, e.g. at doors, the form of construction will present many difficulties but one solution might be ingress and egress by tunnel.

The effect of atmospheric pressure and composition are more obvious. If the pressure is too low or too high for the human body, pressurization one way or the other is obviously necessary. Moreover, materials must be used which are chemically unaffected by any constituents of the atmosphere. For instance, on the outer planets, materials affected by methane, ammonia, water or hydrogen must be used with caution. On airless worlds, of course, or in space, any materials may be used without fear of adverse chemical effects.

Thousands of specialized and individual problems also arise. For instance, how would the setting of concrete and mortar be affected by these considerations? The setting of concrete is not fully understood, but it is clearly

independent of a terrestrial atmosphere, as concrete will set satisfactorily under water. On the other hand, the right temperature is essential, as is the presence of water. Concrete must be kept wet whilst setting, and concreting must not be carried out in frosty weather. This seriously reduces its range of application in planetary engineering, though "ciment fondu" offers better possibilities as it is quick-setting and rapid-hardening, and can be used in frosty weather because it generates internal heat in its setting action.

Would a sewage farm, or the bacterial treatment of sewage, be feasible on another planet, under these conditions? This is an important matter, as the question of sewage disposal will have to be considered on any planetary colony. Sewage utilization, via the nitrogen cycle, will probably be the answer and there are two main classes of bacteria involved, aerobic and anaerobic. The latter, at any rate, as the name implies, would function satisfactorily without a terrestrial-type atmosphere.

THE FOOD AND ATMOSPHERE CONTROL PROBLEM IN SPACE VESSELS

PART II. THE USE OF ALGAE FOR FOOD AND ATMOSPHERE CONTROL

By Norman J. Bowman, Ph.D.

SUMMARY

It has been shown that even on the basis of growth rates actually obtained to date, algae can be used on space vessels advantageously to convert human waste products (CO_2, water, faeces and urine) to edible proteins and fats. At the same time oxygen is liberated to the air in the process. Theoretically this means that a completely closed cycle for food and atmosphere is possible. The weight of algae and equipment required for this at present is such that a trip of five months' duration is necessary to make it preferable to the alternative of carying dehydrated food and liquid oxygen. Further advances in the technology of algae growth will undoubtedly reduce this trip length to less than a month in the relatively near future.

Introduction

In the first part of this paper methods of atmosphere control were discussed in which both carbon dioxide and water were not only removed but recovered for re-use if desired. We shall see that the proposal to be made in this paper is directly dependent on the availability of a feasible method for CO_2 and water recovery.

If we turn to the problem of food on the spaceship, we find there are two alternatives, (*a*) to carry food in dehydrated form, (*b*) to re-synthesize food by some means from the human waste products, water, CO_2, faeces and urine. Chemical synthesis of fats has been previously considered by the author,[1] and, although possible, will involve heavy equipment and very complex reactions. There are other possibilities in this category, however. We may grow our food on the ship by means of hydroponics. This is feasible but in the present stage of our knowledge it appears that a very large amount of space and weight will be required because of the relatively slow rate of growth of food plants.

Food Synthesis by Micro-organisms

Other alternatives not previously considered are to obtain food from human waste products through use of an organism, e.g. fungi, yeast or algae. Of major importance also in such a scheme is the fact that CO_2 will be removed from the air and replaced by oxygen by these organisms. This would make it necessary to carry little if any oxygen for breathing and under such circumstances a completely closed cycle is theoretically possible for carbon, hydrogen and oxygen. Yeast and fungi have been used to convert human wastes to edible food and in the last war the Germans prepared yeast on a large scale from wood chips.[2] However, both these types of organisms appear to have practical disadvantages, not the least of which is a rather slower rate of growth than is desirable. In the case of algae more data are available and fairly rapid growth rates have been achieved on a large scale.

In order to compare the use of algae in a closed cycle with the other possibility—that of carrying dehydrated food—we will set up two parallel cases and determine what duration of space voyage is required to give a saving in take-off weight through the use of algae.

Case 1. Food is carried in dehydrated form. Liquid oxygen is used to replenish the air, and a small refrigeration unit and compressor are required to keep it liquefied. Tanks are built into the hull of the ship to reduce incremental weight. Water and CO_2 are removed by means of a calcium oxide regeneration system as discussed in Part I of this paper. Additional water needs are obtained by distillation of urine.

Case 2. Water and CO_2 are removed by means of a calcium oxide regeneration system. Urine, faeces, water and CO_2 are used as nutrient sources for algae to grow food and liberate oxygen to the atmosphere.

Calculation of Case 1

A man needs approximately 500 g. of dehydrated food per day to give the 3,000 calories required for light activity. This is based on a calorie content of 4 cal./g. for protein and carbohydrate and 9 cal./g. for fats. (The discrepancy of various literature values for the human oxygen requirement has been discussed in a footnote in Part I of this paper.) A value of 1 kg./man/day was chosen as a conservative average and is the basis of calculations in this paper. Allowing a reasonable additional weight for oxygen tanks, refrigeration and compressor units, etc., we find that a total weight of about 1·7 kg./man/day is required for case 1.

Calculation of Case 2

Algae are known to be capable of growing at a rate of as much as seven times their original weight per day. This, however, is in small-scale experiments and represents the maximum that has ever been obtained. The values obtained in large-scale algae culture experiments are several orders of magnitude lower. Also, by changes of medium of culture, either protein or fats may be synthesized by the same strain of algae. For example, chlorella can produce 50 per cent. protein-50 per cent. fat in the presence of high fixed nitrogen content media. In a reduced nitrogen content media it will produce 85 per cent. lipids.[3,4]

Different strains of algae produce different types of proteins so that by proper choice a balanced amino acid diet can be obtained. Of importance also is the fact that any living organism produces some of the necessary vitamins, hormones, etc. It appears possible by proper choice of several strains of algae to develop a diet that gives not only the necessary calories but which is completely balanced in so far as various specific nutrients are concerned.

The recombination of human waste products to give food through the use of algae requires energy. For this purpose algae use certain wavelengths of light in a process of photo-synthesis. Considerable study has been made of the large-scale growth of algae,[3,4,5,6] and while we have done little more than scratch the surface of the tremendous possibilities in this field, sufficient data is available to make a quantitative estimate of the potentialities. We will first review briefly the conditions presently known for rapid algae growth.

Best Conditions for Rapid Algae Growth

It has been found that solar light of high intensity or that rich in ultra-violet will retard algae growth or actually kill the organism. We need the longer wavelengths in the infra-red region and it is therefore probably desirable to use filters to ensure proper wavelength and intensity. This is particularly true if we were to use the solar light of space, which is extremely rich in ultra-violet. The algae absorb light rapidly but do not use it immediately so that it has been found best to have intermittent exposure to light with periods of darkness in between.

Algae also grow best under constant agitation and when illuminated in thin wall sections which allow all algae equal exposure to light and access to CO_2 and nutrients. The rate of light absorption and utilization will be best under these conditions, resulting in faster growth and higher yields.

The carbon dioxide which the algae require is usually fed in the form of a 5 per cent. mixture with air, but it is reported that algae are saturated with CO_2 when in equilibrium with as little as 0·1 per cent. in air. This is lower than the concentration of CO_2 which we plan to have on the spaceship (0·2 per cent.). In addition we can increase the available CO_2 by use of several atmospheres of pressure in the algae tank. This is of interest as it may be possible to eliminate the calcium oxide regeneration system. In such a scheme we would bubble air under pressure into the algae tank and eventually vent it in another part of the cycle. The algae would reduce the CO_2 concentration and increase the oxygen content. In addition the air released would be saturated with moisture at three atmospheres and expansion would automatically control the humidity. The alternative to this is to make use of the calcium oxide regenerative system and thereby use a higher concentration of CO_2 in the algae feed. This has an advantage in requiring much lower rate of air flow and no compression equipment.

Normal room temperature appears to be about the most favourable for algae growth, although it is not critical. The nitrogen balance is important in determining the type of food which the algae will produce. Some reports actually indicate that algae can fix nitrogen from the atmosphere in small quantities and this should be investigated further. It is customary to add

nitrogen in the form of ammonium or potassium nitrates. With the latter salt the range is between 1·25 and 6·0 g./l. for optimum results, and above 10 g./l. growth is inhibited strongly. The nitrogen from human excretions is in two forms. There is about 20 g. per day of urea in urine and the faeces contain 5 to 10 per cent. of more complex nitrogen compounds. This material should be a readily usable source of nitrogen to the organism. In the algae tanks at take-off, the proper solution would be already established in the algae tank and the nitrogen from human wastes would replace that consumed by the algae.

Mineral constituents are very important to algae growth and must be present in small quantities. However, larger amounts must be avoided as they are often toxic. It is difficult to keep all needed minerals in solution. For this purpose a chelating agent such as ethylene diamine tetracetic acid is commonly used.

Bacterial contaminants are variously reported as not detrimental and as very harmful to algae growth. Faeces are extremely high in bacteria and for this reason it will probably be desirable to feed the raw material consisting of water, urine and faeces through an ultra-violet irradiation system, to kill the bulk of the bacteria. This does not offer any problem and the dead bacteria are a usable food source to the algae.

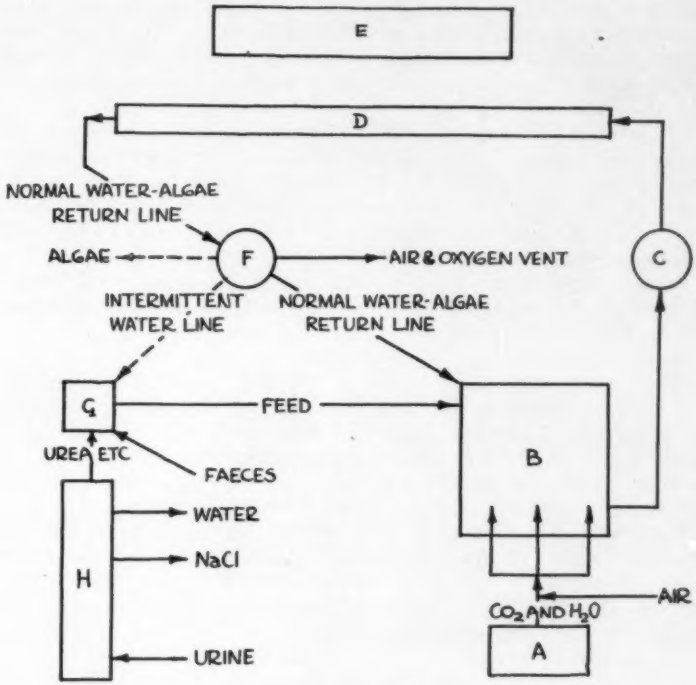
To date, by proper choice of the above conditions, particularly the use of annular chambers for irradiation, a culture density of 55 g./l. and a daily yield of 2·5 g./l. have been obtained.[5] It is on this basis that we will make our calculations for case 2.

Calculation of Case 2 Completed

At a daily yield of 2·5 g. dry algae per litre, it is obvious that we will need 200 l. of algae culture per man to produce food and purify the air in a completely closed cycle. The apparatus which has been designed to carry this out is shown in the diagram on page 163.

For the present we are assuming that CO_2 is removed from the air by means of a calcium oxide regeneration system and after mixing with air, is fed into the main algae tank *B* in concentrated form. This tank consists of a cylinder of magnesium 3 mm. thick and 0·6 m. in diameter and height. The feed, consisting of faeces, urea and recycle water is fed into the tank and mixed by the rapid recycle through pump *C*. This circulating pump has a capacity of ten gallons per minute, thus giving complete turnover of algae suspension in five minutes. The pump delivers the suspension into the radiation trough *D* which is 6·5 m. long, 30 cm. wide and 4 cm. deep. It is made of magnesium and is covered with a transparent plastic filter. The light irradiation equipment *E* delivers the proper intensity and wavelengths to the algae after passing through the filter.

From here the algae pass into the centrifugal separator *F* which serves two purposes. First of all it is here that the necessary gas is vented continually to maintain a pressure equilibrium with the CO_2 injector. Centrifugal separation will be necessary as the three phase solid-liquid-gas system will not separate of its own accord in the absence of gravity. In addition to this use, the separator



A. Muffle furnace for CaO recovery.
B. Main algae tank.
C. Circulating pump (1/20 h.p., 10 gal./min.)
D. Trough for algae irradiation.
E. Light source.
F. Centrifugal separator.
G. Ultra-violet irradiation to kill bacteria.
H. Absorption tube for de-salting.

FIG. 1.

will, at intervals, separate the algae *from* the water for use as food, instead of merely gas from algae-water. At a culture density of 55 g./l. it will be necessary to process only about nine litres of algae culture per day to supply this food.

After absorbing energy in the irradiation trough, algae will be returned to the main tank during most of the cycle. Here after mixing with CO_2 they will grow rapidly. The capacity of the trough and the pumping rate are such that the algae on the average will be irradiated for two minutes and will then spend three minutes in the darkness of the main tank before being recycled. This cycle can be changed in any way desired by altering the dimensions of the

trough and the pumping rate. The carbon dioxide is fed into the cycle just after irradiation so that maximum utilization of CO_2 will be maintained and little of it vented later on. Vent gas will be depleted in CO_2 and much enriched with oxygen by the algae growth, thus taking care of the problem of air purification.

The problem of minerals is one of the main uncertainties in the present investigation. Algae consume minerals in their growth and a balance between requirements of the algae and the quantities present in human excretions should be possible. If not, it may be necessary to remove periodically salts from the nutrient bath to reduce their concentration there and also make the minerals available to human consumption.

The only place where definite difficulty is anticipated is in the matter of sodium chloride. About ten grams per day is excreted in the urine and the algae apparently will not consume nearly this much. This salt is required for human consumption and if allowed to build up in the algae culture medium, will eventually kill the algae. We have two alternatives. One is to de-salt the urine before feeding it to the algae, the other is to de-salt the algae medium itself periodically. In either case we will have the problem of separating NaCl from urea and other minerals which are needed by the algae. Because of the quantities of materials which would have to be treated, it appears better to work with the urine than with the algae culture medium.

A combination of a solid absorption agent with an ion exchange resin should provide a workable and simple system for this separation and would be capable of easy regeneration. The urine would be passed through the absorption bed which would remove most of the solids, giving pure water suitable for drinking. Elution with a water insoluble agent would separate the urea from the bulk of the sodium chloride. The other inorganic salts would then have to be separated from the sodium chloride by further elution involving the ion exchange portion of the absorption set-up. The urea and minerals other than sodium chloride would be recycled into the algae tank. Separations would not be sharp in such an arrangement but would be sufficient to give a practical system.

The feed cycle would be operated only once a day and that just after having harvested the daily algae supply. This would give a 24-hour period between introduction of the feed and the harvesting of food and thereby the lowest possible quantity of unconverted human excretions as contaminants in the food. It is known that human waste products can be completely converted by the algae in 24 hours, so that aspect of the problem appears to be satisfactorily taken care of. In addition, the faeces and recycle water in the form of a slurry are irradiated in tank *G* to kill most of the bacteria. It should be noted that roughage in the diet such as cellulose will be unaffected and will be filtered off with the algae in equilibrium quantities. Accumulation of material which the algae cannot digest is a possibility. If such proves to be the case it will be necessary to find another organism which will convert such products to a form usable to the algae. Otherwise the cycle will quickly break down.

Having now determined a workable system and knowing that we require 200 kg. of algae suspension to produce the food needed for one man, it is of interest to estimate the added weight of equipment as described above to carry

out the algae growth cycle. A rough estimate for various parts of the system is given below.

TABLE II

A.	CaO regeneration system (same as Case 1. Wt. not considered).	
B.	Algae tank	8 kg.
C.	Pump	3
D.	Irradiation trough	12
E.	Irradiation lamps	5
F.	Centrifugal separator	5
G.	Ultra-violet irradiation	4
H.	Absorption tube	10
	Miscellaneous	3
	Total weight	50 kg.

This value of 50 kg. for equipment weight should be ample. With the 200 kg. of algae suspension we have a total weight of 250 kg. per man for this completely closed cycle for food and atmosphere purification.

It should be noted that there is little possibility of substantial saving of equipment weight by the use of larger systems to serve more men. The equipment weight is only 25 per cent. of the weight of the algae suspension and we can hope for substantial saving only through increasing the algae yield per litre per day and thus permitting this same sized system to serve more than one man.

Comparison of Cases 1 and 2

We are now ready to make our comparison with case 1. In the latter we found that about 1·7 kg. per man per day of food and oxygen was required. This gives a point of equality with the algae system of 145 days, or slightly less than 5 months based on our present technical knowledge. This is a rather long time but in the operation of a space station or on a voyage to Mars such as calculated by Von Braun[7] where a trip of over three years is projected, this algae system looks feasible and attractive. In both cases substantial weight saving in delivered payload, and therefore tremendous saving in fuel and number of required trips, can be made.

One modification of the system described above would be to use air directly as feed gas for the algae instead of first separating the CO_2 by use of calcium oxide. We could dispense with the muffle furnace and save about 20 kg. However this is not a clear saving as an air compressor would be needed, plus certain changes in the equipment, to make it workable under a pressure of several atmospheres. This additional weight is estimated at 10 kg. so that we save perhaps 10 kg. net. This reduces the equivalence point from 145 to 135 days, which is inconsequential.

The most important aspect of this is as yet unmentioned. Biologists generally agree that we have not reached the maximum obtainable rate of algae growth. While the present figures indicate it is already feasible in a five-month trip, a two- or three-fold increase in yield of algae per litre per day would make this scheme extremely attractive for almost any type of space voyage. It appears reasonable to expect to reduce the minimum voyage duration to less than a month by further experimental investigation of algae growth conditions.

There is already extensive research on large-scale algae culture for other purposes. The Universities of Stanford, Texas, California and Maryland and the Arthur D. Little Co. are all known to be working on this problem. Their interest is not in space flight but rather in low cost conversion of sewage from cities into high protein food suitable for livestock. They are faced with the problem of large algae yields per unit of time and space in order to make this commercially practical without prohibitive investment costs. It is probable that they will find solutions which are directly applicable to space flight since the fundamental problems of rapid growth and edibility are common to both purposes.

In addition to providing food and replenishing oxygen, any type of plant life produces a freshness in the air not obtainable by other means. Just why chemical purification or even the use of compressed air causes unpleasant sensations in breathing is not understood. It is, however, a well recognized phenomenon and once again our algae system offers an attractive solution to a difficult problem.

Considerable research must be done considering such variables as ionic concentrations, pH, light wavelength and intensity, CO_2 concentrations, etc., to obtain maximum algae growth. In addition, for the purposes of space flight, it will be necessary to make the following additional studies:

(1) Types of algae most suitable for a completely balanced diet.
(2) Actual tests on humans over extended periods of time.
(3) Determination of nutrient additives if No. 2 above proves they are needed.

The immediate potentialities of algae as a means for controlling the atmosphere and food supply in a space vessel have been shown. This may also be useful for other purposes, e.g., air control in an atomic submarine, making it possible for such a submarine to stay under water indefinitely.

Conclusion

The lengths of space voyages and the different requirements regarding food and atmosphere control are summarized as follows:—

(1) On voyages of less than 8 days for a 5-man crew or 25 days for a one-man crew, space vessels will find it advantageous to carry dehydrated food, liquid oxygen and to purify the air by means of lithium oxide. The minimum weight requirement for this is about 2·6 kg./man/day.
(2) For voyages longer than 8 or 25 days and shorter than 5 months it will be desirable to carry dehydrated food and liquid oxygen and to purify the air with a calcium oxide regeneration system. The weight requirement varies from 2·6 down to 1·8 kg./man/day depending on the length of the trip.
(3) On voyages longer than 5 months algae could be used for food and atmosphere control. The weight requirement varies from 1·8 kg./man/day to zero depending on the length of the trip.
(4) In the future, more rapid algae growth techniques should permit algae eventually to be useful in trips as short as a few weeks.

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THE ATOMIC HYDROGEN ROCKET

By D. J. H. Wort

SUMMARY

The possibility of using mon-atomic hydrogen as a rocket fuel does not yet seem to be generally appreciated. The hypothetical mon-atomic hydrogen rocket has several unique and interesting characteristics and, in contra-distinction to more conventional motors, it is possible to derive quite a precise mathematical analysis in simple terms. The author proceeds to derive the characteristics of an ideal motor from elementary considerations, and finally concludes that when mon-atomic hydrogen becomes a manageable material, a rocket motor rivalling all others in simplicity and performance may be constructed.

Introduction

It is generally accepted to-day that interplanetary flight using present-day chemical fuels is only a marginal possibility,[1] it being considered that the minimum exhaust velocity required to render such flight feasible is of the order of 7 km./sec. The most energetic fuels so far considered, usually involving fluorine as oxidant, appear to have exhaust velocity capabilities of up to 4·5 km./sec. or thereabouts. However, there exists one chemical fuel which, whilst as yet unmanageable, would prove extremely useful, having a potential exhaust velocity of 18 km./sec. or over. This fuel is mon-atomic hydrogen, formed, with some difficulty, by the dissociation of ordinary molecular hydrogen. On recombination to molecular hydrogen, a large amount of heat energy is liberated:—

$$2H \rightarrow H_2 + 103{,}400 \text{ cals.}$$

i.e., 51,700 calories per gramme of fuel.[2] This is far greater than any other chemical reaction, possibly because the recombination of hydrogen atoms to form a molecule more closely resembles a physical change, and a physical change frequently involves greater energy than a chemical one.

Thus there exists the possibility of a fuel of great value, requiring no oxidant (although a catalyst may prove necessary, as in the "cold" hydrogen peroxide motor), and providing an exhaust gas, pure hydrogen, of the lowest possible molecular weight, having therefore the highest possible exhaust velocity for a given chamber temperature.

Mon-atomic Hydrogen Characteristics

Considering the above reaction to go to completion, and taking the specific

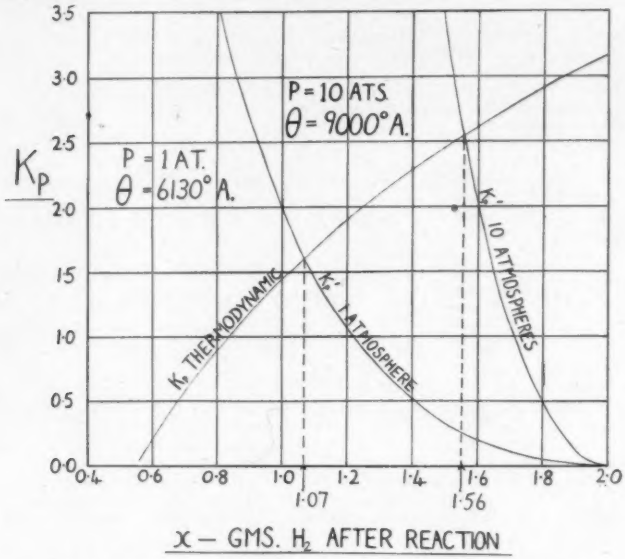

FIG. 1. Solution of Equation (5) for P = 1 at. and P = 10 ats.

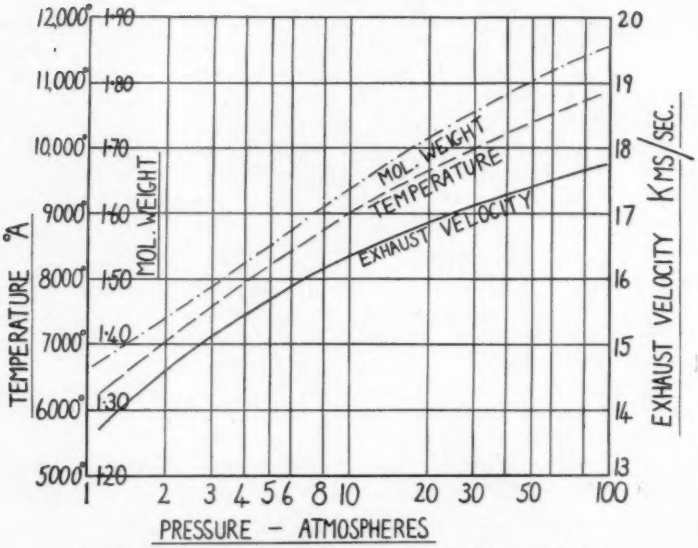

FIG. 2. General characteristics of the atomic hydrogen rocket.

heat at constant pressure of hydrogen to be 9 calories/g. mol./° C., at high temperatures, the temperature of the hydrogen by the reaction should be 103,400/9 or about 12,000° A. (° Centigrade absolute, or ° K.). However, mon-atomic hydrogen may be produced by raising molecular hydrogen to high temperatures, i.e., the reaction can proceed in reverse:—

$$H_2 \rightarrow 2H - 103{,}400 \text{ cals.}$$

In fact both reactions will proceed at once, and an equilibrium mixture will be obtained,

$$2H \rightleftharpoons H_2$$

neither reaction proceeding to completion. Thus the fullest possible amount of heat energy will not be obtained, and the specific heat and molecular weight of the product gases will not be those of molecular hydrogen only.

However, it is possible to calculate the degree of completion of the reaction for any given conditions, knowing the equilibrium constant K_p of the reaction at one atmosphere pressure and its variation with temperature θ. A graph of K_p against θ is given by Sutton[3] for comparatively low temperatures, and from this and thermodynamical considerations an expression may be found connecting the generalized equilibrium constant, K^1_p, with the temperature θ in degrees absolute, to a fair degree of approximation:—

$$K^1_p = 2{\cdot}33 \log_e \theta - 18{\cdot}59 \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (1)$$

If, in the mixture, after the reaction of 2 g. of mon-atomic hydrogen we have x g. molecular hydrogen and hence $(2 - x)$ g. of mon-atomic hydrogen, then,

$$K_p = \frac{(2-x)^2}{x/2} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (2)$$

and $$K^1_p = P.K_p \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (3)$$

where P is the prevailing pressure.[4] The specific heat of the reaction mixture is found to be $5 - x/4$ cals./° C./g., assuming the specific heat of mon-atomic hydrogen to be 5 cals./° C./g., and that at the temperatures quoted the vibrational quantum of the hydrogen molecule will be satisfied, giving a specific heat of 9 cals./° C./g. Thus the temperature attained will be

$$\theta = \frac{51{,}700x}{2(5 - \frac{x}{4})} \text{ ° A.} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (4)$$

Thus we have now derived two independent expressions for K^1_p, and may equate them thus:—

$$2{\cdot}33 \log_e \left[\frac{51{,}700x}{2(5 - \frac{x}{4})}\right] - 18{\cdot}59 = \frac{(2-x)^2}{x/2}.P \quad .. \quad .. \quad .. \quad (5)$$

This equation may be dealt with in two ways. If details of performance at a selected pressure are required it is necessary to plot two graphs, one for each side of equation (5). The value of x for the selected P may be found from the intersection of the two graphs, and having x, the other performance details may be calculated. In Fig. 1, chamber pressures P of 1 atmosphere and 10

atmospheres have been selected; all calculations are to slide-rule accuracy only.

Alternatively a broader view of the characteristics of a hypothetical motor may be obtained by the somewhat simpler method of determining the values of P which satisfy equation (5) for various values of x, and also determining the temperatures resulting from these values of x by means of equation (4). θ may then be plotted against P, see Fig. 2.

The average molecular weight of the exhaust gases is given by:—

$$m = \frac{2}{2 - \frac{x}{2}} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (6)$$

This is also plotted in Fig. 2. It should be noted how closely the curve for m follows that for θ. The final factor affecting the exhaust velocity of a rocket motor is γ, the ratio of the specific heats of the exhaust gases. The variation of this factor with the composition of the exhaust gases, i.e., with x, is somewhat difficult to estimate. The author, however, derived the following expression and tentatively assumed it to hold:—

$$\gamma = \frac{20 - x}{12 + x} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (7)$$

Having now all the necessary information, we may calculate the ideal exhaust velocity, C, from the expression[3]:—

$$C = \left[\frac{2\gamma}{\gamma - 1} \cdot \frac{R\theta}{m}\right]^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad .. \quad (8)$$

Values for C, in km./sec., will be found on Fig. 2. It is interesting to note that above about 9000° A. the exhaust velocity is affected only by the variation in γ as the quotient θ/m remains sensibly constant.

Dilute Mon-atomic Hydrogen

The temperatures quoted or inferred above may well seem impracticable, and it may be doubted whether the large-scale manufacture, stabilization, and handling problems of pure mon-atomic hydrogen will ever be solved. However, there exists another method of using mon-atomic hydrogen which gives equally interesting performance figures under far less exacting conditions.

If instead of pure mon-atomic hydrogen, a dilute "solution" of mon-atomic hydrogen in molecular hydrogen is used, the advantages of low molecular weight exhaust gases and a reducing atmosphere in the rocket chamber are retained, but due to the lower specific energy content of the fuel, the temperatures attained will be considerably lower and within the range now considered normal for rocket motors. The exhaust velocity will, of course, also be considerably lowered, but it is still in the "very high" region by present day standards, and the advantages of lowered temperature probably outweigh the diminished performance.

The lower temperature also results in the reaction proceeding almost to completion; it being permissible to ignore the fact that an equilibrium is actually obtained. Some calculated results are given in Fig. 3 in which θ and C are plotted against percentage of mon-atomic hydrogen in the fuel supply. The

chamber pressure will not affect the temperature attained as the simple reaction involved will proceed to completion irrespective of pressure.

It will be noticed that the ideal exhaust velocity has quite a respectable value even at low concentrations of mon-atomic hydrogen. It should, however, be realized that these figures are somewhat susceptible to disturbing influences, and that at the low reaction temperatures the initial temperature of the gas (here taken as 273° A.) will have considerable effect upon performance. The results should therefore be considered as a rough approximation only, to those which would be obtained in practice.

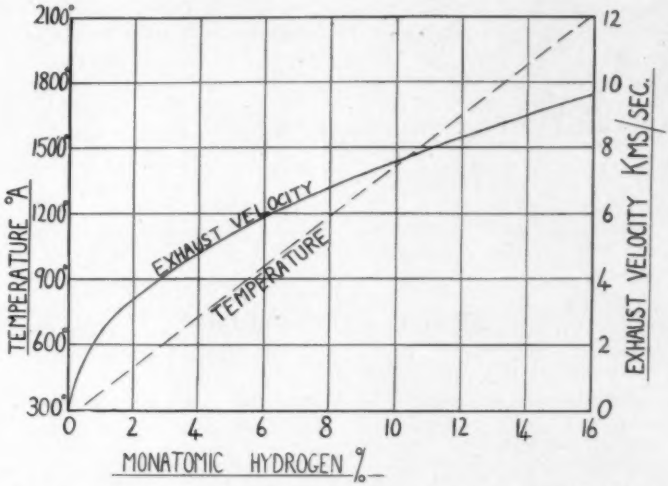

FIG. 3. Theoretical performance of the dilute mon-atomic hydrogen rocket.

The diluted mon-atomic hydrogen motor has the further advantage that its exhaust velocity, and hence thrust, may be varied simply and precisely by altering the "mixture strength," no adjustment of oxidizer flow being required (there being no oxidizer), whilst the mass flow may be kept constant. This precise and reliable variation of thrust is much sought after and difficult to attain in conventional rocket motors. There would appear to be one grave disadvantage in the use of mon-atomic hydrogen as a rocket fuel. This is the low specific gravity. It would seem reasonable to expect the specific gravity of liquid mon-atomic hydrogen to be even lower than that of ordinary molecular hydrogen, and even in the liquid state these fuels would be excessively bulky. However, the performance of the rocket should be sufficiently high to allow quite heavy fuel tanks to be carried without causing any undue trouble.

It may thus be concluded that when a means of obtaining and storing mon-atomic hydrogen has been developed, or alternatively a method of obtaining it simply and without massive equipment has been discovered (and this may,

incidentally, be one of the ways of utilizing atomic energy), rocket motors with great possibilities may be constructed. Even diluted mon-atomic hydrogen would enable escape velocity to be obtained with reasonable mass ratios, and a rocket motor to run on this fuel could probably be constructed at the present day. This is in distinct contrast to the only other known method of obtaining high exhaust velocities, i.e., the hypothetical nuclear-powered motor. In the author's opinion, high powered "direct" nuclear-fuelled rockets are likely to remain impracticable for a considerable time yet, unless great advances are made in heat transfer techniques, and a type of controlled reactor running at a very high temperature is developed. The other alternative, the ion-rocket, is of course useful only for very low thrusts in vacuo. In short, if exhaust velocities high enough to enable interplanetary flight to be achieved are under consideration, the mon-atomic hydrogen rocket should be high on the list of possibilities.

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(*We are glad to publish Mr. Wort's interesting paper and should like to see some expression of views by chemists, and/or physicists on the prospects of it ever becoming possible to manufacture, and store in bulk*, liquid *mon-atomic hydrogen, even in somewhat dilute form.*—ED.)

SPACE PHYSIOLOGY

BY C. R. ARMSTRONG, B.Sc.

(*Summary of a paper presented to the North-Western and Midlands Branches on October* 18, 1952, *and January* 10, 1953, *respectively.*)

Space medicine problems may be summarized briefly as follows:

(1) Tolerance of conditions resulting from the absence of terrestrial factors and increases of solar energy.
(2) Maintenance (artificially) of semi-terrestrial conditions in the ship and protection from radiated energy and meteorites.
(3) Means of sustaining life on other celestial bodies.

A further complex of physiological problems arises due to the speed of the ship and the velocity of the mental processes involved in its control, the so-called "dead distances." A third complex of problems is more of a psychological nature involving problems of psychic aptitude, fatigue and claustrophobia.

I am going to deal only with two of the vast numbers of physiological problems, namely, sub-normal gravitation and oxygen supply.

Physiologically speaking, sub-normal gravitation involves two basic questions:

(1) What are the effects of a constant reduced level or absence of gravity?
(2) What is the effect of changes in gravity upon leaving and returning to the Earth?

Physiologists hesitate to make definite predictions in both cases. In a gravity-free state our weight decreases to zero, but the power of our muscles remains the same. This strange discrepancy in muscle energy in gravity-free space may bring difficulties to our sensory-motor system. The movements of our limbs are controlled by a threefold sensory system, muscle and pressure sense of skin being best known. If a limb be anaesthetized and muscle sense be eliminated at the same time, we are still able to make very accurate movements. For instance, suitable stimuli applied to a muscle will cause it to contract without the intervention of the nerve fibres which ramify amongst its substance, as is shown by the fact that muscle which has had its motor end-organs paralyzed by curare will still respond to direct stimulation. The drug curare does not interfere with the release of the transmitter (nerve impulse), but prevents the released acetylcholine from producing a contraction.

The third component in the controlling mechanism are the Vater Pacini corpuscles, which are large receptors (nerve terminations for receiving afferent impulses) found in the subcutaneous tissues of the hands and feet and in the neighbourhood of tendons and joints. They probably record pressure and therefore respond to deformation.

It is conceivable that this third component, through adaptation, could compensate in part, in the gravity-free state, for the elimination of both the others, which must be considered as gravireceptors.

I am a little optimistic, therefore, as to the sensory-motor system in gravity-free space, regarding the sensory control of movements of our entire body, if a modified basal tonus of the muscles which depend on the vestibular apparatus does not spoil the picture. (The vestibular apparatus is a complex sense organ situated in the head, which is stimulated by (*a*) gravity and (*b*) rotary movements, and plays an important part in postural activity.) It gives rise to incoming impulses which reflexly adapt the position of the trunk and limbs to that of the head and enable the erect position of the head and the normal attitude of the body to be maintained.

The movement of the whole body will involve floating in the air of the space ship and orientation for movement will have to be accomplished optically. Fish can be trained to an optical orientation in space, but we do not know whether man can adjust to purely optical orientation.

The absence of gravity involves less difficult problems with reference to respiration and circulation, The cardiac muscle maintaining its output has less work to perform since the weight of the blood is nil. We do not know whether or not the heart will be able to adapt itself to this situation in gravity-free space. If it can adapt itself, will it be able to accept the additional stresses when gravity returns? At the return to Earth the only weak spot in the circulation seems to arise. We have no reason to assume that respiration will be impaired by the absence of gravity; one difficulty however arises, not to the respiratory apparatus itself but to the ambient air. The expired air containing only 16·5 per cent. oxygen, but 4·1 per cent. carbon dioxide, as against 21·06 per cent. oxygen and 0·04 per cent. carbon dioxide in inspired air, will remain in front of the astronaut. Therefore a method of ventilation must be provided for the space ship's air to prevent formation of these localized concentrations of carbon dioxide.

While the human body may behave normally, other objects in the space ship will not. Attempts to drink a glass of water will prove to be difficult due to the wetting properties of the water under zero *g* conditions. A practical method of taking fluids would be to use a rubber bottle and nipple so that the fluids can be squeezed out of the container. Solid foods pulverized or in tablet form could be stored in sealed light metal containers and used as required. But a certain amount of roughage must also be included if normal digestion is to take place.

Simple acts such as walking, writing and sleeping become problems in the absence of gravity. Most of the problems arising out of zero *g* conditions will be minor annoyances, but some of them, seemingly trivial, could be of such a critical nature as to endanger the entire ship.

Life in the space ship will be far from simple; the crew will have to be a group of intensely trained co-ordinated men. They will not have the opportunity of making the same mistake twice.

This, in short, sketches the picture of gravity-free space with only some of its physiological problems. We can only guess at the facts; experiments must give the final answer. In case gravity-free space involves too many difficulties of a physiological nature, the physiologist will have to demand a constant slight acceleration of the space ship to attain a certain amount of quasi-gravity.

A comfortable physiological environment requires an adequate oxygen supply. I would like to discuss only a shortage of sufficient oxygen in the space ship. The consumption of oxygen by the astronaut will be low under zero *g* conditions as no work has to be performed to overcome gravity. Metabolic rate would not exceed that of basal metabolism to any significant degree. If exercise is performed to prevent muscle atrophy, the maximum oxygen consumption might be in the region of 500 litres per day per person. The oxygen problem can be further minimized by utilizing the upper physiological limit of increased oxygen pressure. We know the minimum of oxygen pressure required in the air is about 100 mm. Hg; below this figure the individual succumbs to altitude sickness. We know that man can tolerate pressures up to 425 mm. Hg. for prolonged periods without any injury; at pressures above this level, symptoms of oxygen poisoning will manifest themselves.

As economy has to be practised regarding oxygen consumption in the space ship, it would appear advisable to use the upper range of physiological tolerance of oxygen pressure.

If 42 cubic metres of air at normal atmospheric pressure are available to a person in a space ship, the normal oxygen pressure of 160 mm. will be reduced by respiration, so that the lower physiological limit of oxygen pressure would be reached in six to seven days. If, however, the pressure of oxygen was increased to say 400 mm., i.e., close to the upper physiological oxygen limit, the lower physiological limit of oxygen would be reached only after 33 days. If we utilize the high pressure of oxygen, considerable economic advantage is achieved. It will be obvious that this method should be used with regard to prolonged flights in the ionosphere. The only disadvantage would be an increased danger of fire.

Many have discussed the probability of a collision of a space ship with a

meteorite. What would be the physiological effects in case such a collision should actually occur? The effects would be similar to that following leakage of a pressure-cabined aircraft in the stratosphere, but could of course be more violent. Within a few seconds conditions of hard vacuum could be attained, though naturally this would depend on the size of the hole; the most probable penetrations would lead to leaks which might take hours to detect. If decompression were very rapid, in addition to effects of a super-acute anoxia there would be a super-acute gas oedema of the tissues and subsequent destruction of the tissues; the skin, for example, would form large blisters filled with oxygen, carbon dioxide and nitrogen, etc. Such manifestations can be observed in rabbits exposed to explosive decompression up to 60,000 feet in low-pressure chambers. These manifestations are, of course, a violent form of aero-embolism.

I would like to conclude this discussion with this brief remark. Maybe space flight physiology belongs to the realm of imagination, but by its study we may add better understanding, for example, to our sensory-motor system, by trying to visualize its function in the absence of gravity. In any case the subject of space physiology will give momentum to medical sciences.

APPENDIX

Calculation of the Physiological Tolerance of Oxygen Pressures

Assuming that voyage starts with cabin containing 42 cu. m. of air at normal atmospheric pressure:—

(1) Cabin filled with ordinary air at 760 mm. Hg. pressure.

Partial pressure of oxygen is 160 mm. Hg., so volume of oxygen is about 8·8 cu. m.

In reducing this to the lower limit of 100 mm. Hg., 60/160 of the oxygen is used up, = 3·3 cu. m., which would last 6·6 *days* if consumed at ½ cu. m. (500 l.) per day.

(2) Cabin filled with air at 760 mm. Hg. pressure, but containing oxygen at 400 mm. partial pressure.

Volume of oxygen is about 22 cu. m. In reducing this to 100 mm. partial pressure, 300/400 of the oxygen is used up, = 16½ cu. m., which would last 33 *days*.

The same result would be obtained if the cabin were first filled with ordinary air and the extra oxygen then added, raising the pressure in the cabin to more-than-normal; the partial pressure of oxygen would still start at 400 mm. Hg. and would correspond to 22 cu. m. at normal pressure, and would keep the occupant alive for just as long.

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IS ASTRONAUTICS ESCAPISM?

By H. E. Ross

Astronautics is a science—really an aggregate of many sciences—and as such must stand or fall according to the strength and validity of its arguments. It would in fact be unscientific to ignore criticism, and no science worthy of the name will do so. However, astronauts have to date been far more concerned in rebutting technical criticism than in examining and countering criticism and misunderstandings of their practical philosophic aims. Indeed, apart from describing the gains in knowledge which could result from the exploration of space, little on this subject except platitudes may be found in any work on

astronautics. This is lamentable, because it leaves the impression that astronautics, whilst *hoping* for the best, is actually nothing more than a grandiose technical adventure—a soulless searching for physical facts largely regardless of present and future human welfare. Fortunately for astronautics—and mankind—the reverse really applies.

In the first place, it seems unlikely that professional rocket engineers deserve to be dubbed "escapists," for their interest in astronautics is an eminently practical one. To them, the problem of designing a vehicle capable of controlled flights through space is the supreme challenge offered to their ingenuity. If attempting to create something new and immensely difficult is to be escapist, then certainly much human advance has been based upon that subconscious "fleeing from reality" which is implied by the contemptuous appellation "escapism."

Nor can it be said of astronomers and scientists generally that they have their heads in the clouds and their feet firmly planted in space. On the contrary, they are irresistibly motivated by a desire to see, know and understand, and so have excellent reason for being interested in establishing contact with other worlds. What is discovered may or may not be capable of utilization, but it would be crass foolishness to think that conceptual extensions of knowledge are worthless.

Of course, even in the above cases, interest in astronautics may not be due to a single urge, for human motives are usually based on a *mixture* of impulses. This fact is often disastrously overlooked by people who should know better: including, be it said, some who have applied the sweeping oversimplification "escapism" to astronautics.

Bearing this in mind, we must now generalize to include the laymen who constitute the bulk of interplanetary enthusiasts. Here it is apparent that all kinds of motives and mixtures of motive from Mah to Mahi are involved. The novelty of the proposals and a desire to understand them is one composite compulsion. Love of adventure, even at second-hand, together with curiosity concerning the unknown, are also powerful allurements. The wish to be associated with something wonderful, and withal rather mysterious, is another potent attraction. The egotistical urge which seeks satisfaction in the acquisition and personal dissemination of recondite knowledge is a further possible reason for interest in astronautics. Again, even the colossal scale and scope of the interplanetary concept acts as a powerful magnet, for human beings are, strangely enough, fascinated by sheer magnitude.

These reasons could be extended almost indefinitely, for the rising star of astronautics compels attention. One may disagree with interplanetary aims, but one cannot ignore the implications. Philosophers, theologians, metaphysicians, mystics, and politicians—are discovering that astronautics provides startlingly new, and in some cases profoundly disturbing, food for thought. Again, there are some (the altruists *and* the exploitists) who incidentally or purposively make money through their knowledge of astronautics. That, at least, can scarcely be called "escapism!"

Here then, one way and another, are some good occupational, professional and recreational reasons for interest in astronautics. However, that is not

really the point of the present discussion, for one can have excellent *reasons* for wanting to do something and still be an escapist. Thus, in the special case we are considering, it is possible that personal frustrations or a general dissatisfaction with the state of things in this world, may generate a wish to escape from it. If such an attitude of mind results in neglect of one's duties and responsibilities, then that is the kind of escapism implied in the opening sentence of this article.

A person will also be that kind of escapist if he is a utopian idealist, labouring under the delusion that starting again in a new world automatically puts everything right. Nothing, of course, could be more removed from possibility. Obviously so, for a person can never escape from himself, however far he travels. Nor, if he is an extra-terrestrial colonist, could he escape from the society of his fellow pioneers. There is, in fact, no hope of philosophical and sociological salvation through the colonization of other worlds unless we are prepared, first, and well in advance of technical adequacy, to make a thoroughly honest and completely objective study of human ends and means. That, with all due deference to philosophers and sociologists, has never yet been done. All have had some axe to grind or theologic kink which clouded their minds. The one terse sentence of Alexis Carrel who said, *"we are the victims of the backwardness of the sciences of life over those of matter"* points to the root of many of our troubles. Mankind has not yet realized that techniques are only the means to an end, not an end in themselves. Astronauts would do well to remember that the spaceship is only the interplanetary bus—the means, not the end; also that the problems of human organization are largely independent of *location*; furthermore, that to advance again and to reap happiness instead of grief, man must make a new approach to himself. It was C. H. Waddington who said, *"Man is the only animal to discover the secret of getting results in this material world, which is to let one's actions be governed by an objective analysis of the situation. Our task now is to enable this analysis, which we call science, to get results when it is applied to politics."* This is the kind of approach which astronautics, sooner or later, must make. That is not escapism—it is, pre-eminently, "First things First." Manifestly so, for we cannot begin to put things right until we know as certainly and objectively as possible, what is wrong *now*. If, on the other hand, astronauts are content to see another Wigan or another Lhasa perpetrated on the Moon, Mars or Venus, then the writer for one sees no point in it.

If, however, we take it that one interplanetary aim is the establishment of extra-terrestrial communities dedicated to higher orders of human dignity, wisdom and happiness, then it naturally follows that the technical maturity which astronautics envisages must be matched by social maturity. It may indeed be said that the battle for the solar system can be won technically, yet prove a barren victory, if, in mastering nature, we fail to master ourselves. Even if we never cross space, that, unquestionably, is what we must do.

There will probably be no disagreement over these sentiments. There will probably, however, be doubt that questions of human aims and especially human organization can be resolved in a generally satisfactory manner. To this the writer replies that a scientific appraisal of human nature will establish

aims and show how they can be attained in a far more certain way than is otherwise possible. There is in fact already good agreement in the matter of aims. This much should be apparent to anyone who has read the UNESCO symposium *Human Rights*. On the other hand, there is considerable disagreement over means. One reason for this is that whilst many people are capable of *analysis*, which reveals aims, very few are capable of *synthesis*, where the practical extrapolation of society from basic humanitarian concepts is entailed. The value of a scientific approach is that it simplifies this task. Having established a mutually consistent set of aims it is possible, almost automatically, to produce from them a mutually consistent practical set of means.

To extend the discussion further would mean departing from the title of this article. However, probably enough has been said to show that astronautics can contain just as little or just as much as one wants it to contain, but that in its entirety it is, "inescapably," the Science of Man.

One day a landing on the Moon will be made. No one with any imagination and intelligence will underrate it as other than the supreme technical triumph of all time. It is to be hoped that not a few will also recognize its vital philosophic significance. One would like to think that amid all the technical jubilation somebody will get up and say:

"Remember! For the first time since Adam the slate is clean."

NOTES AND NEWS

Informal London Meeting

In view of the great success which attended the informal meeting held on November 5 last year, it has been decided that a similar meeting should be held during the summer months, and all members are invited to the "Mason's Arms," Maddox Street, W.1 (just off Regent Street), for another informal meeting on Wednesday, August 19. As before there will be no set programme or time-table and as many as possible of the Council will endeavour to be there from approximately 6 p.m. onwards.

It is hoped that all members (and potential members!) who can do so will come along.

Informal Birmingham Meeting

An informal meeting of the Midlands Branch will be held at the Cambridge Inn, Cambridge Street, Birmingham, 1, from 7 p.m. onwards on Saturday, September 12.

This meeting is being held for the purpose of enabling Branch members to meet each other, and to meet the Branch Officers, and also to discuss anything that the members find that they have in common. Nothing will be barred, from discussing the merits of Science Fiction stories to airing opinions on the Society, and how it should be run.

The Cambridge Inn is situated at the rear of the Civic Centre, Broad Street, and is approached along the side of the Air Terminal building. Light refreshments will be available.

North American Aviation, Inc.

NATIV, a North American Aviation guided missile, nears a tall launching tower where it will be test fired. NATIVS, travelling at supersonic speeds, have reached trajectory altitudes of 10 miles during recent tests.

Visit to an Observatory

Mr. P. A. Moore, who has a 12 in. reflector at his home at East Grinstead, has very kindly offered to show the future objectives of the Society to interested members.

The period August 13 to August 18 inclusive is particularly favourable, and interested members are invited to write direct to Mr. Moore at Glencathara, Worsted Lane, East Grinstead, Sussex.

East Grinstead can be reached by Green Line coach, which run at half-hourly intervals from Victoria Coach Station.

The Evolution of Life in the Universe

Those who heard Professor J. D. Bernal's talk last November on *The Evolution of Life in the Universe* may remember his passing reference to a certain "Bill Pirie." This was but a faint echo of a vigorous controversy which two doughty opponents have been carrying on in the scientific Press ever since Professor Bernal lectured to the Physical Society in November, 1947, on *The Physical Basis of Life*. "Bill" is none other than N. W. Pirie, Head of the Biochemistry Department of Rothamsted Experimental Station and, like Professor Bernal, a Fellow of the Royal Society.

It all started with Pirie writing a letter of comment on the original lecture; then Bernal quoted and answered the comments when publishing his lecture in book form in 1951; then Pirie complained that his letter was not intended for publication, and some of its best points had been ignored. So he wrote a full review of the book in Penguin *New Biology 12*, entitled his review "Vital Blarney," and ended up by saying of Professor Bernal: "we must put down to pure Irish whimsy his decision to write a book on life."

Now Bernal has countered with "Keep off the Grass: a Review of a Review," in *New Biology 13*. He writes of Pirie: "in his delight in castigating the impudence of anyone—not even a biochemist—who pretends to knowledge about the origin of something that does not exist, he has allowed himself to express opinions of his own of an extravagance of scepticism that far exceeds anything he charges against me."

Well, what is the fuss really about?

In the first place, Pirie says that discussions on the origin of life and its nature have been going on for so long that it is difficult now to say anything original on the subject; and that the only significant new idea, in the last 40 years, is Haldane's suggestion that organic substances would accumulate as a result of the sun's ultra-violet light acting on the ammonia and hydrocarbons in the primitive atmosphere. Bernal replies that, since the classic writings on the subject, three new major areas of relevant knowledge have been opened up; geochemistry, the energetics of chemical reactions, and the biochemistry of the interaction of enzymes with protein substrates.

Then there is an argument about proteins which, Bernal points out, are present in all life. Pirie asserts that they needn't have been originally, and Bernal agrees, suggesting that there may once have been even a clay particle "that did inefficiently some, but just enough, of the things that proteins do to-day." But Pirie can't see what advantage clay has over any other adsorbing

HIGH ALTITUDE EMERGENCY PRESSURE SUIT.

A new high altitude flying suit, developed by the Air Research and Development Command's Aero Medical Laboratory at Wright Air Development Center, Dayton, Ohio. It provides airmen with protection in the event cabin pressurization is lost while flying at high altitudes. The pilot is also wearing the latest one-piece Air Force helmet, featuring electrically heated face piece to avoid frosting, respiratory valves, microphone and earphones. Oxygen breathing hose, at front of the helmet, is connected to aircraft's oxygen system and also to emergency oxygen bottle strapped to the pilot's leg. Emergency oxygen is used for high-altitude bailouts to provide oxygen until pilot has parachuted to safe altitude. The suit fits the pilot snugly, but is comfortable to wear. Tubes along pilot's arms and legs are used to pressurize suit when protection is needed. Integrated with the suit is an anti-*g* device which operates automatically when pilot is subjected to high gravity forces caused by aircraft manoeuvres.

mineral particle, so Bernal tells him "first that it is many million times more abundant and secondly that it is indefinitely extendible and can cope with large molecules."

When Bernal says "there is only *one* predominating life, derived from one chemical basis," Pirie objects that "bacteria and algae make a magnificent range of new and funny structures," and later complains that Bernal is quite unaware of the limited range of organisms with which biochemists have so far worked. Then, of course, there has to be "an injunction to the cobbler to stick to his last," to which Bernal can reply that Priestley was not a chemist, nor was Pasteur a biologist.

And a definition of life? Pirie writes: "life is not a property of a system; it is a statement about our attitude of mind towards the system." But Bernal, in his lecture to the B.I.S., preferred to be more positive, quoting with approval a definition proposed by John Perret in the course of an article in *New Biology 12*, called "Biochemistry and Bacteria," which anyone interested in the fundamentals of living substances would do well to read.

Perret's definition, which would need a glossary ten times its own length to make it comprehensible to most readers, is—"Life is a potentially self-perpetuating open system of linked organic reactions, catalyzed stepwise and almost isothermally by complex and specific organic catalysts which are themselves produced by the system." So now you know!

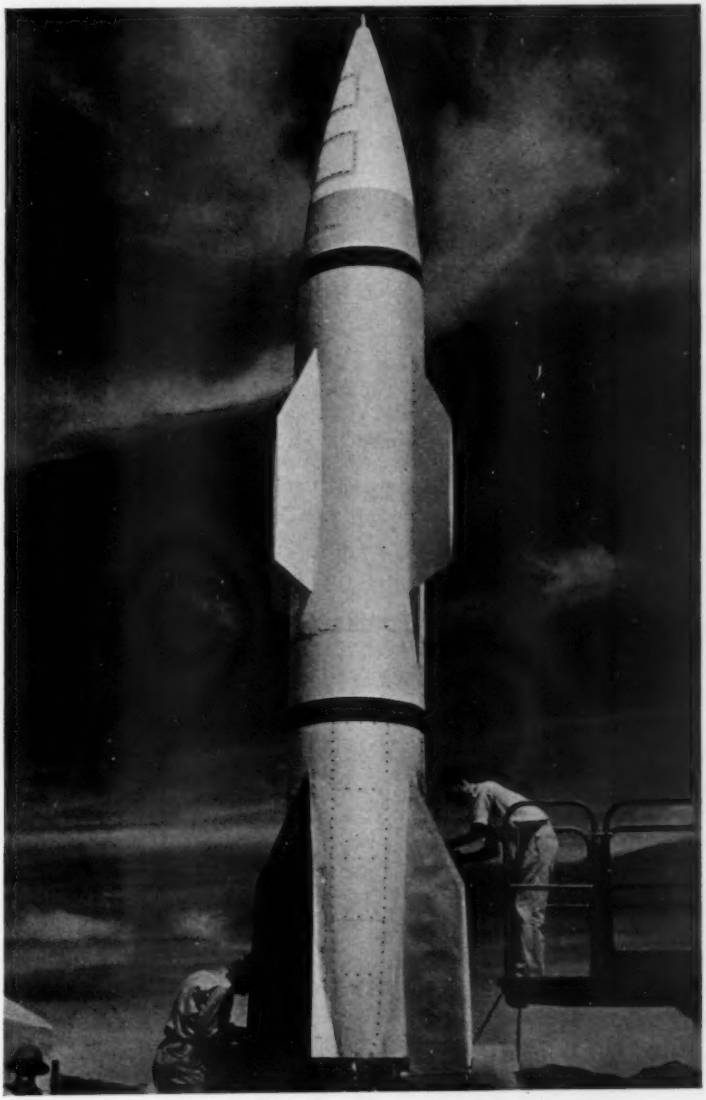
From the World's Press

The stone which Mr. R. W. D. Perkins dropped into the House of Commons political pond generated ripples in the newspaper world that are still coming back to us.

Some papers cautiously reported the questions and answers without comment, but quite a number had positive opinions to express. Only one or two thought it time Astronautics was put in its proper place of no-priority, and hoped it would stay there—the rest, while not actually condemning government policy, indicated that they didn't agree with it. Making due allowance for the fact that government policy, whatever it may be, is everyone's Aunt Sally, it is nonetheless apparent that we have some good friends and champions in newspaper circles. This is not only most encouraging but also surprising, for it is quite evident from several cuttings that the press in general have not yet discriminated between the blood-thirsty and "inhuman" extravagances of science-fantasy and the scientific extrapolations of astronautics. Or at least if they *have* discriminated, then they must have concluded that astronautics, like all other news, needs pepping up; indeed, one gets the impression that if a Flying Saucer landed and didn't kill anyone, it wouldn't be reported.

Typical of the adverse remarks just alluded to is a commentary in the *Western Daily Press* of Bristol dated January 27, which says:—

"Perhaps yesterday's somewhat laconic exchanges in the Commons on inter-planetary travel researches helped to keep our feet on the ground, for certainly some counter is needed to the bizarre and fantastic conceptions of



The American "Hermes" rocket.

super-men and super-spaceships which enliven certain cartoons and films and feed gaping imagination beyond the dreams of Jules Verne."

It does not seem to have occurred to the writer that astronauts may be just as anxious as any to avoid the cataclysms foreshadowed by science fantasy, which are indeed necessary warnings as to what *might* happen. The important thing is to see that they do not. Any other view leads ultimately to the conclusion that *all* progress is dangerous, and should be stopped. That conclusion might have been operated by our ancestors when they discovered fire; in which case a great number of us would not have been born and the rest of the present generation would be savages.

In contrast to the *Western Daily Press*, the January issue of the South African magazine *Industry and Trade* came out rather strongly, albeit facetiously, on the side of astronautics. Here the writer began by saying that although he objected to the State undertaking any commercial or industrial enterprise which properly belongs to the field of the private *entrepeneur*, he recommended space travel as an exception because only Government servants could be spared from their offices long enough to make the protracted interplanet voyages. "There is no doubt at all," he adds, "that such journeys are becoming imminent and that many readers will witness them before the turn of the century or before they get telephones, whichever is the later."

In contrast again we have *The Scotsman*, which although gloomily pessimistic about the uses and outcome of man's extra-terrestrial ambitions, is nevertheless resigned to their achievement. But, says *The Scotsman* of February 23, Sir Andrew McFadyean, vice-president of the Liberal Party, seems to take a different view. "He said on Saturday that the only Elizabethans of our day were the scientists and airmen who want to explore interstellar space and start an air ferry to the moon. In other words, the Government, and the Opposition for that matter, are just an unadventurous lot of stay-at-homes."

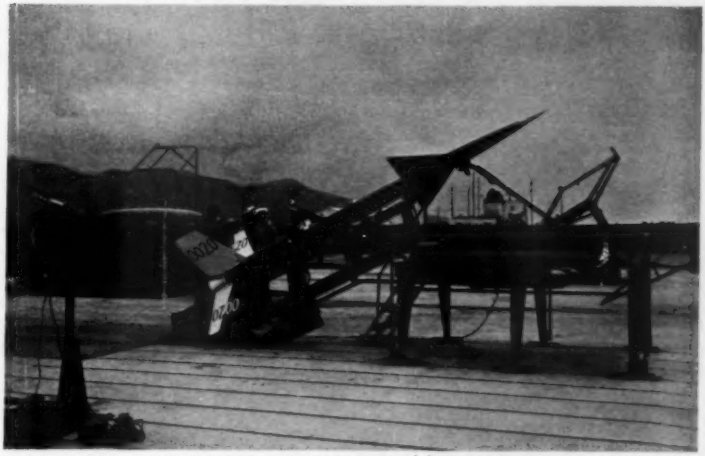
A leading article in the *Daily Express* was equally enthusiastic, saying—"Is it (State interest in astronautics) really such a ridiculous idea? Any more ridiculous for instance than would have been a demand for a select committee on aviation in the year 1900? No doubt that, too, would have been derided. The quest for knowledge that has carried man's exploration of the skies so far and so high in so short a span of years will take him to the moon and to the stars much sooner than scoffers believe."

We, of course, think so too. That is why we want Britain to have a place in the venture.

* * * *

British newspapers of February 27 carried news that the Armstrong Whitworth Aircraft Company, a member of the Hawker Siddeley group, is setting up its own test centre for rockets and guided missiles at Salisbury, a village near Adelaide, South Australia. According to *The Times* report, "The station will work in co-operation with the company's headquarters at Coventry, where research is being conducted. It will have a factory used entirely for rockets and guided weapons, as well as a testing range."

Quoting the managing director of Armstrong Whitworth Aircraft, *The Times* continues—"Mr. H. M. Woodhams said yesterday that the company



Sparrow in firing position on launcher.

An air-to-air guided missile manufactured by Douglas Aircraft Co. Few details are available but unofficial sources state that the missile has an all-up weight of 280 lb. and employs a double-based solid propellant.

Bell X1 rocket driven aircraft is reputed to have travelled at 1,500 mph.

The aircraft is 31 ft. long with a 28 ft. wing span. Tanks carrying liquid oxygen and ethyl-alcohol feed for 4·2 mins. four rocket chambers giving a total of 6,000 lb. thrust. This aircraft, normally carried aloft under a B-29, could also take-off from the ground and on one occasion climbed 23,000 ft. in 100 secs.

proposes to use its Australian station for "shooting tests into the stratosphere and ionosphere and beyond." This was a private venture of the Hawker Siddeley group, but they would be working with departments of both the United Kingdom and Australian Governments."

Mr. H. M. Woodhams is also quoted by *The Scotsman* as saying—"'Two years ago our chairman, Sir Frank Spriggs, said that our work on rockets and guided missiles staggered the imagination. We are now at a stage where we can bring these one-time fantastic dreams to reality.'"

* * * *

Various papers from about the middle of March onwards lifted a tiny corner of the security veil, or rather blanket, which covers British rocketry. After all, one cannot fire even a skyrocket, much less a guided or philosophically speaking *mis-guided* missile, without attracting some attention.

Certainly, as for instance David Knight, writing in *The Irish Independent* of March 27, says—"no veil of secrecy can hide the noise that attends the firing of weapons from the Welsh cliffs overlooking the Atlantic ocean. Almost every day for months past the gossip of local residents has been punctuated by roars, frightening reverberations, and the unearthly whine of air being sucked in as guided missiles streak from the launching base."

Nor can we be surprised at people wondering, and possibly praying, when things like this are going on. We again quote David Knight:—

"Sometimes, too, things happen in and around Aberporth that provide a talking point for weeks on end in the local inns. Not long ago a rocket was seen to roar up into a clear sky where, at a great height, it seemed to stop, turn a somersault, gyrate this way and that, turn horizontally and proceed for a short distance, double back on itself, then finally head for the open sea. It was obviously under radio control from the camp. [*Was it so obvious!—Ed.*]

"Then there was the rocket that was seen to shoot straight out from land, turn, and charge landwards at frightening speed. It is believed to have landed somewhere near the village of Llechryd, about five miles inland, and to have buried itself in the boulder clay of a field, without doing any damage."

* * * *

Under the heading "Rocket tests in forest start scare" the *News Chronicle* of March 12 reported that explosions and strange roars have scared people living near Button Oak, near Bewdley, Worcestershire. So, says *The Times*, "yesterday Imperial Chemical Industries announced: 'We have taken over an area of the Wyre Forest. The rockets are held down in a heavily constructed test bed, and measurements of thrust, pressure and temperature are made while they are operating. There is no possibility of the rockets being projected into the air.'"

In other words, we take it, the necessary precautions have been made to see that Button Oak stays buttoned.

* * * *

We look forward confidently (albeit not immediately) to the time when British universities will follow the lead of American colleges in providing courses in astronautics. Two such courses were announced recently, one to be given by Professor T. D. Phillips at Marietta College, Ohio; the other at St. Louis University. Commenting on the former, the *New York Journal of Commerce* says: "Now, at last, serious students will be able to comprehend comic books."

To this we can only reply that it takes a good physicist to write them!

Just how seriously these studies (of rocket propulsion problems, *not* comic strips!) are being taken, may be judged by an announcement in *Chemical and Engineering News* (Washington), that the Daniel and Florence Guggenheim Foundation will grant a total of $36,000 for 1953 Guggenheim Jet Propulsion Fellowships. The purpose of these Fellowships is to select and train outstanding men for basic research and leadership in the future development of rockets and jet propulsion at Princeton University and the California Institute of Technology.

* * * *

Press announcements in early April state that the U.S. Armed Forces have developed a rocket which can fly at four times the speed of sound, and that a 4,600 m.p.h. rocket is planned. According to other reports appearing near the same date, the French radio-guided "Matra M.04" has broken all French records with a speed of about 1,118 m.p.h. in level flight. It is mentioned that the trial took place at Colomb-Bechar, Algeria. The statements say that this rocket is not in general production but is designed to carry an atomic explosive.

* * * *

The problems of what to do with old razor blades, surplus radio-active materials, and ex-dictators, may eventually be solved by shooting them into space in rocket ships. In the meantime an even more pressing problem rears its head—what to do with old spaceships, left-overs from exhibitions.

This bad enough, but Scarborough recently faced the dilemma of finding room for a brand new £6,000 one, 60 feet long by 20 feet high. Reports in the *Scarborough Evening News* and *Hull Daily Mail* read like something out of Beachcomber, only Dr. Strabismus being missing.

Sites all over the town were considered: the Aquarium top—but that would entail building up, and would cost too much; the Grand Skating Rink—but that had to be maintained as an open space and in any case the space ship was too wide; the West Pier—but here it would get in the way of the fish. . . . Speaking with some feeling on this last proposal, Councillor Tringham said: "The Chairman of the Harbour Committee, myself, and officials have been down there. We have put the spaceship here, we have put it there, we have turned it round, and we have done everything feasible in the hope that we could get it on the West Pier."

A position at the bottom of St. Nicholas Cliff Gardens was suggested by Councillor Smith, who said the shelter there was a "dark gloomy corridor looking something like an underground lavatory, and an effort should be made to make it more attractive." Commenting, Alderman Chapman urged that no hasty

decision should be made at the Council Meeting, and that the committee should take another month to consider what he termed "Councillor Heath Robinson's suggestion."

However, according to the *Hull Daily Mail* it seems that the Council adopted a recommendation of the Parks Committee that no objection should be raised to the spaceship being placed at the northern end of Alexandra Gardens.

We sincerely hope it doesn't wind up outside the B.I.S. offices, which piece of road is reserved exclusively for the use of visiting Flying Saucers.

* * * *

The *Continental Daily Mail* of February 16, in an article by Gordon Young entitled "The Great V2 Mystery," recounts an interview with a former leading member of the so-called "Marco Polo" French Resistance organization, in which the B.I.S. is mentioned. He says:—

"Who would have thought . . . that Britain's desperate war against Hitler's V2 rockets and flying-bombs could have begun in a room in Liverpool before the war, and could have spread, in due course, to a factory in neutral Sweden and to a school for blind children at Lyons? . . .

"The man who gave me this new sidelight on the secret V-battle was Jacques Bergier, a physicist who was chief technician of the 'Marco Polo' organization.

"Early in the war M. Bergier had established a clandestine radio link with London. 'Then,' he told me, 'at the beginning of 1942 one of my agents told me he had met a Russian *émigré* who had worked as an engineer at Peenamunde, and who had described what seemed then fantastic things about a new rocket weapon.

"Soon after, I discovered that a certain French physicist was organizing supplies for the Germans of liquid oxygen—the fuel for rocket propulsion.

"I was convinced that this was an important discovery, and sent full details of it to London. But at first I was not believed. No reaction at all came from the British military experts. This was, of course, long before supplementary reports on Peenamunde had been sent to London by the Polish Underground.

"Then I remembered that, before the war, I had been in contact with a little group who called themselves the British Interplanetary Society.* They met in a room in Liverpool, and I think most people at the time regarded them as just harmless cranks.

"So I radioed to British Intelligence that they should get into touch with those gentlemen, who could convince them that the V1 and V2 weapons were theoretically possible."

"Whatever action was taken in London," continues Gordon Young, "from that moment onwards M. Bergier's reports were taken seriously and the whole special network of 'Marco Polo' was brought into being, to concentrate entirely on German rocket preparations."

* *None of the present leading members of the B.I.S. were, in fact, approached on this matter, possibly owing to the fact that they were widely dispersed on various missions and could not be contacted.—Ed.*

* * * *

According to *The Daily Telegraph* of April 20, a company interested in prospecting for uranium and other deposits on the Moon has been registered in New York State under the name of Moon Metals and Minerals Inc. and hopes to have £357,000 in capital by the end of the year. *The Daily Telegraph* adds: "Its founder, Mr. Richard de Touche-Skadding, explorer and lecturer, says that for some years it will confine its activities to encouraging projects for landing unmanned rockets on the Moon."

ABSTRACTS

Edited by J. HUMPHRIES

Abbreviations of titles of journals were given in the May, 1950, issue of the *Journal*, and addenda have appeared in subsequent issues. The following is a further addendum to the list.

Occ. Not. Roy. Astr. Soc. — Occasional Notices of the Royal Astronomical Society.

Many of the articles noted are available on loan to members resident in the British Isles. Requests should be addressed to J. Humphries, 97, Churchill Avenue, Southcourt, Aylesbury, Bucks.

AIRCRAFT

See also abs. no. 193.

(160) **Jet assisted take-off.** T. VON KÁRMÁN. *Interavia*, **7**, 376-379 (*July*, 1952). History of J.A.T.O. in the U.S. and general review of its applications.

(161) **Weapons of air defence.** K. W. GATLAND. *Flight*, **63**, 219-222 (*Feb.* 20, 1953). Discusses possibilities of conventional interceptors, rocket-propelled interceptors and guided missiles.

(162) **French announce Mach 1·5 interceptor.** *Aviation Wk.*, **58**, (11), 15 (March 16, 1953).
The S.O.9000 Trident has one Turbomeca Marbore II 880 lb. thrust turbo-jet at each wing-tip and a 9,000 lb. rocket in the tail.

ASTRONOMY

See also abs. nos. 174, 176.

(163) **The Moon.** D. W. G. ARTHUR *et al.* **1**, (3), 22-28 (*May*, 1952).
Periodical of the B.A.A. Lunar Section containing recent lunar observations.

(164) **Photometry of the planet Uranus.** G. D. ROTH. *Vega*, **1**, 2-3 (*Jan.*, 1953). Discussion of the variations in brilliancy of Uranus, which are small, but do not agree well with theory. Study of these changes may improve our knowledge of the physical condition of the planet.

(165) **Star-dust from the missing planet.** F. K. DALTON. *J. Roy. Astr. Soc. Canad.*, **47**, 10-14 (*Jan.-Feb.*, 1953).
Discussion of the theory that asteroids and meteors were formed by the break-up of a planet formerly circling the Sun between the orbits of Mars and Jupiter, and some new researches on the débris left by the meteorite which made the Coon Butte crater in Arizona.

(166) **Does anybody live on Mars?** M. CLURMAN. *Pop. Sci. Mon.*, **162**, (2), 126-130, 260, 262, 264, 266 (*Feb.*, 1953).
Popular review of present knowledge of conditions on Mars.

(167) **Vulcan.** O. J. EGGEN. *Publ. Astr. Soc. Pacif., Leaflet No.* 287 (*March*, 1953). Summary of the story of this non-existent planet.

(168) **Astronomy from the space station.** F. L. WHIPPLE. *Sky and Telescope*, **12**, 151 (*April*, 1953).
Survey of the advantages of an astronomical observatory built beyond atmospheric limits.

ASTRONAUTICS

See also abs. no. 168.

(169) **The problem of an interplanetary expedition.** W. VON BRAUN. *Universitas*, **7**, 733-739 (*July*, 1952). (*In German.*)
Discussion of project to take expedition of 70 persons to Mars.

(170) **Space travel.** D. DESOUTTER. *Rolls-Royce Bulletin*, 1-7 (*July*, 1952).

(171) **Shall we live to see the space-ship?** W. LEY. *Natur u. Technik*, **6**, 217-219 (*Aug.*, 1952). (*In German.*)
Predicts first flights 1965-70.

(172) **Basic astronautical research on an international basis.** J. STEMMER. *Natur u. Technik*, **6**, 245-247 (*Sept.*, 1952). (*In German.*)
Condensed version of lecture to 3rd International Congress on Astronautics, Stuttgart, 1952. Proposes setting up of Institution or University for Astronautics and establishing a journal in several languages.

(173) **Destination space.** S. VASUDEV. *Indian Air Force Quarterly*, **2**, (4), 64-75 (*Oct.*, 1952).
Prospects for space-flight.

(174) **The rocket and the future of astronomy.** A. C. CLARKE. *Occ. Not. Roy. Astr. Soc.*, **2**, 127-136 (*Dec.*, 1952).
Summary of present achievements in rocketry of interest to astronomers and assessment of possibilities for future. Covers fundamentals, high-altitude research, earth-satellite vehicles, escape missiles, spaceships, space-medicine and astronomical problems. Concludes that, with existing techniques, small automatic missiles could be put into stable orbits around Earth and later of Moon and planets. Economical development of space travel only possible by production of efficient atomic drive and by obtaining propellant mass from sources of low gravitational potential (e.g., Moon, asteroids, smaller planets).

(175) **Space travel: can we cross the last frontier?** *Platform*, 22 pp. (*Jan.*, 1953).
General review of the pros and cons of space-flight, discussing all aspects.

(176) **The juvenation of Mars.** W. PROELL. *J. Space Flight*, **5**, Pt. I, (1), 1-7 (*Jan.*, 1953); Pt. II, (2), 1-5 (*Feb.*, 1953); Pt. III, (3), 1-5 (*March*, 1953).
The providing of Mars with an atmosphere and climate suitable for human habitation is considered. If oxygen was produced by photosynthesis then a total importation of 10^{14} tons of water would be necessary. It is suggested that if Jupiter VI consists of ice then its orbit could be changed so that it intersected that of Mars.

(177) **Life in the box.** W. VON BRAUN. *Natur u. Technik*, **7**, 54-55 (*Feb.*, 1953). (*In German.*)
Discussion of problems of living in a spaceship cabin.

(178) **Picking the men.** *Collier's*, 42-48 (*Feb.* 28, 1953).
Problems of living in space—weightlessness, cosmic rays, etc., and outline of methods of choosing crew for spaceships.

(179) **How we'll live on Mars.** A. P. ARMAGNAC. *Pop. Sci. Mon.*, **162**, (3), 158-162, 262, 264, 266 (*March*, 1953).
Description of Mars base for scientific exploration party of 33 people.

(180) **Four steps to the Moon.** K. JACOBS. *The Frontier*, **16**, (1), 10-11, 17-22 (*March*, 1953).
Elementary mathematics of step-rockets and space-flight.

(181) **The evolution of the spaceship.** L. R. SHEPHERD and A. V. CLEAVER. *Science-Fiction Plus*, **1**, (1), 54-55 (*March*, 1953).
Critical review of von Braun's plans for 70-man Mars project.

(182) **Interstellar flight.** L. R. SHEPHERD. *Science-Fiction Plus*, **1**, (2), 56-60 (*April*, 1953).
Popularized version of lecture to B.I.S. (see *J.B.I.S.*, **11**, 149-167 (*July*, 1952)).

ATMOSPHERE

(183) **From the troposphere to the exosphere.** *Natur u. Technik*, **6**, 190-191 (*July*, 1952). (*In German.*)
Methods of investigation and properties.

(184) **Pressures, densities and temperatures in the upper atmosphere.** The Rocket Panel, *Phys. Rev.*, **88**, 1027-1032 (*Dec.* 1, 1952).

Averaged and internally consistent values of pressure, density and temperature from ground level to 220 km. compiled by U.S. groups are presented.

(185) **Rocket upper air research.** H. E. NEWELL and J. W. SINY. *J. Amer. Rocket Soc.*, **23**, 7-13 (*Jan.-Feb.*, 1953).

Review of work to date (34 *refs.*).

BIOLOGY AND MEDICINE

See also abs. nos. 177, 178.

(186) **From aviation medicine to space medicine.** H. STRUGHOLD. *J. Aviation Medicine*, **23**, 315-318, 329 (*Aug.*, 1952).

History of events leading to formation of Space Medicine Branch of the Aero Medical Association (25 *refs.*).

(187) **Physiological day-night cycle in global flights.** H. STRUGHOLD. *J. Aviation Medicine*, **23**, 464-473 (*Oct.*, 1952).

Effect of travel on day-night cycle. Persistence of physiological cycle leads to a phase shift with respect to the physical day-night cycle as a result of long-distance east-west or west-east flights (27 *refs.*).

PROJECTILES

See also abs. no. 161.

(188) **Problem child.** F. D. REYNOLDS. *Boeing Magazine*, **23**, 3-7 (*Jan.*, 1953). Review of guided-missile problems.

(189) **Reliability in guided-missile systems.** R. R. CARHART. *Aero. Engng. Rev.*, **12**, (2), 22-26 (*Feb.*, 1953).

Due to its complexity the main cause of failure is the electronic equipment. Reliability is only achieved by taking into account every factor affecting performance. This requires very careful planning. Reliability and accuracy are the two main factors governing the time at which a guided missile becomes operational.

(190) **First details of Boeing GAPA project.** *Aviation Wk.*, **58**, (5), 32-33, 35 (*Feb.* 2, 1953).

More than 100 missiles fired—photos of launching.

(191) **The N.A.C.A.'s role in guided missile research.** J. A. SHORTAL. *Aircraft Engng.*, **25**, 96-100 (*April*, 1953).

Description of aerodynamic research carried out at Wallops Island with rocket-propelled models. 1,800 firings have been carried out at test speeds between M = 0·6 and 4·0. Radar tracking and doppler velocity radar are used to obtain flight data, sometimes with the addition of telemetry for special measurements.

RADIO AND ELECTRONICS

(192) **F-M recording in guided missiles.** A. A. GERLACH. *Electronics*, **26**, (1), 108-111.

Description of transcriber for use with tape from battery-operated magnetic recorder in a guided missile.

ROCKET MOTORS

(193) **Snarler boosts the jets.** *Aviation Age*, **18**, (5), 44 (*Nov.*, 1952).

(194) **Liquid propellant rocket motors.** B. R. DIPLOCK, D. L. LOFTS and R. A. GRIMSTON. *J. Roy. Aero. Soc.*, **57**, 19-28 (*Jan.*, 1953).

Three papers dealing with theory, design and development. The first covers performance, nozzle design and choice of propellant; the second, the combustion chamber and propellant feed systems; the third, the handling of oxidants, materials, valves, seals, rig testing of components, test bed design and operation and instrumentation.

(195) **The construction and use of solid propellant rocket motors.** R. BERND. *Z. Ver. dtsch. Ing.* (*V.D.I.*), **95**, 12-16 (*Jan.* 1, 1953). (*In German.*)

Nozzle and charge design for double-base propellants. These can be used for burning times up to 50 secs. and total impulses up to 30,000 kg. secs.

(196) **The 1952 A.R.S. Annual Convention: a technical summary.** J. V. CHARYK, I. GLASSMAN, S. I. CHENG and G. SUTHERLAND. *J. Amer. Rocket Soc.*, **23**, 41-43 (*Jan.-Feb.* 1953). Summaries of the technical papers presented at the 7th A.R.S. Annual Convention.

(197) **Flow separation in rocket nozzles.** L. GREEN. *J. Amer. Rocket Soc.*, **23**, 34-35 (*Jan.-Feb.*, 1953).
Curves given for predicting point of separation for conventional nozzles, obtained from experimental work of various workers.

(198) **Some experiments on flow separation in rocket nozzles.** K. SCHELLER and J. A. BIERLEIN. *J. Amer. Rocket Soc.*, **23**, 28-32, 40 (*Jan.-Feb.*, 1953).
Onset of separation is governed primarily by reservoir pressure and nozzle divergence angle. No method for predicting plane of separation is presented.

(199) **I.A.S. summaries.** *Aviation Wk.*, **58**, (7), 43-44, 46, 50 (*Feb.* 16, 1953).
Includes summaries of papers on rocket propulsion delivered at the 21st annual meeting of the Institute of Aeronautical Sciences.

(200) **Rockets race and roar in California.** *Pop. Sci. Mon.*, **162**, (3), 164-165 (*March*, 1953).
Photos of rocket ramp and test stand.

ROCKET PROPELLANTS

(201) **Effect of vibrational excitation on the theoretical performance of the stoichiometric carbon-oxygen propellant system.** J. H. SCHROEDER. *J. Amer. Rocket Soc.*, **23**, 25-27 (*Jan.-Feb.*, 1953).
For frozen equilibrium flow, a lag of vibrational energy states at chamber conditions nearly doubles the reduction in specific impulse, as compared with flow in which complete vibrational equilibrium is maintained. On the other hand, lags in vibrational adjustment have practically no effect on the performance if chemical equilibrium is maintained throughout the nozzle.

REVIEW

Raketenantriebe (Rocket Propulsion)

(By J. A. Stemmer. 523 p.p. + ix. Published by Schweizer Druck-und Verlaghaus A.G., Zurich, 1952. 36s. 0d.)

This book gives a general introduction to the development of rockets and indicates the numerous problems concerning rocket flight and space travel. After a comprehensive historical review, a detailed description of the various types of propellants used for rocket propulsion is given. The application of solid propellants for powder rockets as well as many combinations of liquid propellants are subsequently discussed. The advantages and disadvantages of different propellants are compared and conclusions drawn regarding their application to future developments, due consideration being given to the possibility of using nuclear energy.

The aerodynamic problems arising from high velocity and altitude flight, and the practical application of modern powder rockets is also discussed.

Much space is given to a discussion of rocket motors using liquid propellants. Topics like fuel injection, combustion, exhaust gas flow, propellant supply, and suitability of various constructional materials are dealt with in considerable detail. Many examples of existing test arrangements and descriptions of successful developments are used as practical illustrations of the subject. These descriptions range from the smallest war missiles to the largest guided missiles yet built, and include also piloted rocket propelled aircraft. From these considerations, conclusions are drawn as to the possibility of space travel and problems related to this subject.

Numerous photographs, sectional drawings and tables are used to illustrate these descriptions.

The author has endeavoured to give a complete survey of the subject. He has succeeded in presenting the material in a chronological and lucid way. The theoretical explanations are such that they do not demand prior theoretical knowledge of the subject.

The book is strongly recommended to the reader interested in gaining a really comprehensive survey of rocket development, but the lack of an index is unfortunate and detracts from its usefulness as a work of reference.

W. RIEDEL.

CORRESPONDENCE

Fuel v. Propellant—1

SIR,

I must plead guilty to carelessness over the use of "fuel" in *Interplanetary Flight* and hope to make amends in the next edition! There can be no question that care should be taken over terminology in books of a technical character.

However, everyone will agree that in non-technical books intended for the general public—such as the first two examples quoted by Mr. Cleator—rigorously accurate terminology must often be set aside in the interests of reader-comprehension. There are also cases where strict accuracy would be ridiculously pedantic, and no one will object to the use of "refuelling" where "repropellanting" is really meant!

ARTHUR C. CLARKE.

London, N.22.

Fuel v. Propellant—2

SIR,

While there is little cause for disputing Mr. Shalder's contentions regarding the use of the word "fuel" in modern rocket technology, it is, nevertheless, worth noting that the term is also used in a wider sense as a generic word for substances which are sources of available energy. Thus, in the field of nuclear engineering, the fissile materials, e.g. U^{235}, are termed fuels, because they are energy sources. If one accepts this wider meaning, then there is no crime involved, in the scientific sense, in describing the oxidants as fuels, since they contribute directly to the energy released.

One can imagine that this matter might lead to some controversy in the event of nuclear energy being applied to rocket propulsion, in the manner which has been envisaged by certain writers. We might, in such circumstances, find the rocket engineers at loggerheads with the nuclear engineers, over the question of what constitutes a fuel.

A further point arises in connection with the use of hydrogen peroxide dissociated by permanganate, to drive a turbopump. If one cannot use the term fuel for the peroxide, then one is forced to call it a propellant, which is semanticly incorrect since it is turning the turbine and not driving it *forward*. Considerable simplification would result in this and other applications if agreement were reached on the use of "fuel" as a generic title for energy sources.

L. R. SHEPHERD.

Chilton, Berks.

(This correspondence is now closed.—Ed.)

Markings on Venus

SIR,

In "Solar System Notes—7" (*J.B.I.S.*, **12**, (2), 67), Mr. Patrick Moore considers doubtful the existence of streak features observed on the planet Venus.

This is a little surprising, for a study of drawings by many authorities reveals general agreement on these features.

Schiaparelli in 1877 seems to have been the first to delineate streaks on the planet, and he was followed by Perrotin in 1890 and by Professor Lowell, the true discoverer of the spoke-system. In 1896 Lowell and his assistants detected the curious system that has for so long been discredited. In the years following, the Flagstaff observers were able to observe these marks, and since then many observers have seen them either partially or wholly.

To assume that all these astronomers have been misled by some illusion peculiar to Venus, perhaps by reason of her great brilliance, seems to me to be unreasonable. This is particularly so when it is realized that most of these workers used large excellent telescopes erected in sites chosen for excellency of seeing conditions. For the most part these observations were made in the full glare of the sunlit hours. There is little, if any, disagreement between the various observers of the spoke-system, which contrasts sharply with other observations where only vague shadowy patches are recorded, and which have little in common.

Generally, observers in Europe have recorded only the vague transient features beloved of text-books. Few indeed record linear details, yet the existence of the streaks is denied even though they have been seen at stations much better situated.

It is of interest to point out that, quite apart from the radiating streaks and dusky sub-solar spot, permanent markings exist at what appears to be the south polar zone. This latter region I consider to be—as also does Dr. J. C. Bartlett—a vast elevated plateau, bounded by a range of higher elevations. A large number of observations which I made in 1951 and 1953 have led to this conclusion.

Though Venus is still a planet of considerable mystery, its secrets do seem attainable by persistent research and observation. It may be quite possible that much has already been discovered of its geography, or rather aphroditography, but the vast amount of information which exists needs careful sifting before a close and detailed analysis can be made.

R. M. BAUM, F.R.A.S.

Boughton, Chester.

Mr. P. A. MOORE writes as follows:—

Without wishing to belittle Lowell, a great astronomer, it is undeniable that he was only too ready to see "canals," and even placed them on Mercury and Ganymede. It is true that the climatic conditions at Flagstaff are excellent, but significant that Lowell generally stopped down the aperture of his largest refractor; and his results were not confirmed, in the case of Mercury at least, by any other observer using comparable equipment. Antoniadi's Mercurian drawings, made with the

full aperture of the 33-inch Meudon refractor (which I have myself used) are completely different in character.

I quite agree that the spoke-like markings of Venus have been seen by others as well as Lowell, but it is a fact that they have never been recorded by any other established observer using a large instrument. Mr. Baum has seen them with a 6-inch reflector and although I am well aware of his keen vision, I absolutely refuse to believe that with such an aperture he could record features never seen with far larger telescopes by McEwen, Heath, Denning and numerous others who have made a lifelong study of Venus. The eye is easily deceived, and the dazzling disk of the "Evening Star" is one of the most deceptive of all celestial objects. When I hear of even one famous, well-equipped observer recording the linear features, I will reconsider. So long as they are visible only to tiny telescopes, I must hold to my opinion that they are purely illusory.

Our Neighbour Worlds—1

SIR,

Much as I dislike prolonging this verbal match with Dr. H. P. Wilkins, I must emphatically deny ever having stated that "the lunar ring-mountains have no level ground about the middle." It will further be observed that the description "saucer-shaped" is intended to apply only to one class of these formations, certainly not to walled plains, such as Clavius or Plato. The text of my book leaves no room for misunderstanding on this point.

As regard Callisto, I strive to preserve an open mind in all things and not to exclude any possibility, however remote it may appear, for our knowledge is small.

Finally, there is no unanimity of astronomical opinion with regard to the surface detail and many other planetary features, and every reasonable view of a famous observer having some of the largest telescopes of the world at his disposal deserves at least passing mention in a general presentation of our state of information about the solar system. Some contradictions and a degree of confusion are inevitable if a true picture is to be painted.

V. A. FIRSOFF.

Lochearnhead, Perthshire.

Our Neighbour Worlds—2

SIR,

I feel I must comment on Mr. Firsoff's statement (*J.B.I.S.*, **12**, (3), **143**) that I have given him incorrect information.

I have had no correspondence with him, and assume that he took the diameter of Bailly from a paper of mine written a year or two ago.

A new catalogue of lunar diameters has recently been issued by Arthur which gives an amended value for Bailly, but the difference is small, and in view of its unfavourable position on the Moon's limb, as well as its nature (it has been aptly described as a "field of ruins"), minor errors may well remain.

P. A. MOORE.

East Grinstead.

Planetary Engineering

SIR,

As Mr. Neumark has cited my paper on "Planetary Engineering" in his letter (*J.B.I.S.*, **12**, (3), 146), I should like to comment on one or two points which he has raised, though I agree with some of his remarks, e.g., his advocacy of strictly utilitarian structures.

I admit that I left much unsaid about lunar accommodation, simply because my subject was "Planetary Engineering" and not "Lunar Buildings." As the former title is exceedingly wide in scope and the question of living accommodation only one of its many aspects, I could only devote a few minutes to it. It would be possible to devote a whole paper to the subject of "Lunar Buildings" and perhaps one of the professional architects in the Society will take this as a hint! In any case, I am a civil engineer, not an architect.

Mr. Neumark's idea of balloon-like inflated buildings does not commend itself to me; the problem of ingress and egress would be no easier than in the case of a rigid structure and would, in fact, almost certainly be much more difficult. It would be difficult to fix anything to the walls and, most important of all, although such buildings could be constructed of materials much stronger than those which go into the making of toy balloons, their strength could not compare with that of a rigid structure. Further, I feel that Mr. Neumark has underrated the effect of meteors, temperature and other secondary stresses. I should hate to live in a structure in which I could not even indulge in a game of darts without having to dive for a spacesuit or airlock (also flexible?) every time I missed the board!

One strong point in favour of such inflated buildings lies in the fact that if anything were to go wrong one's end would be quick and merciful.

E. HOPE-JONES.

London, S.E.24.

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